Journal of the Forest Products Research Society

FPRS 8th National Meeting—Woodworkers Industry Show—May 5, 6, 7—Page 23-A

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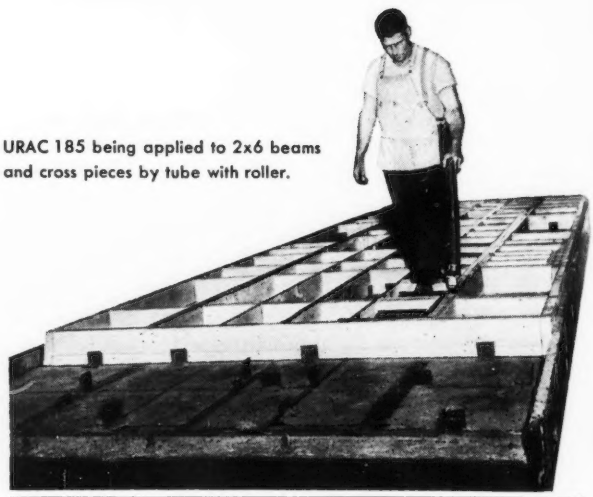

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★ **A COMBINATION YOU CAN'T AFFORD TO MISS—The 1954 Woodworkers' Industry Show, May 5, 6, 7, held simultaneously and in cooperation with the FPRS 8th National Meeting.**

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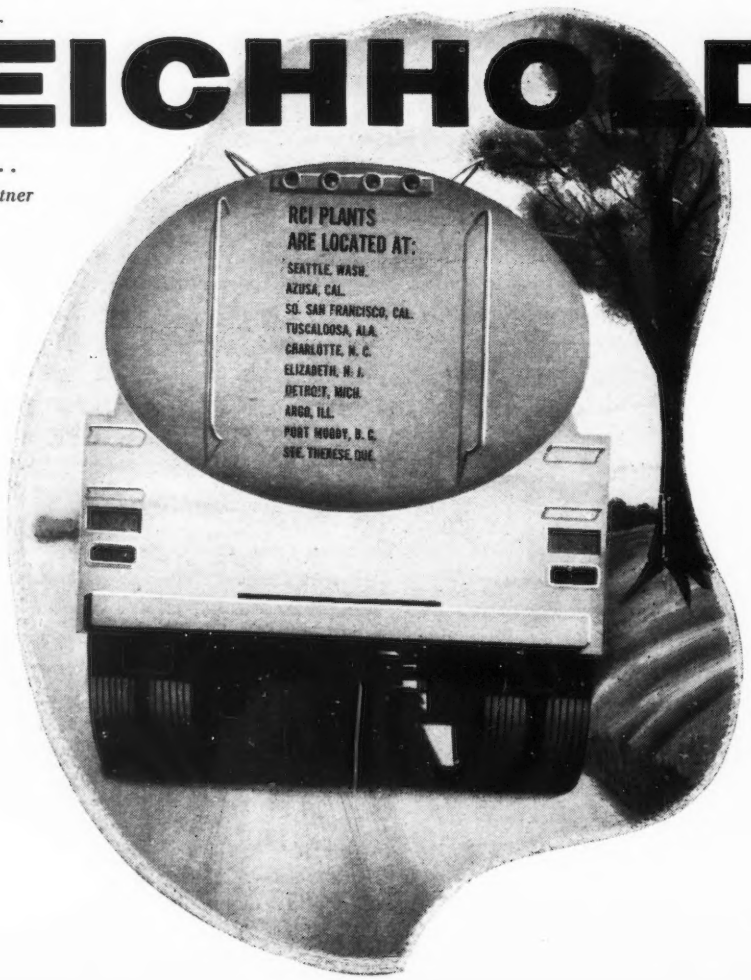

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in Cooperation with

The Woodworkers Industry Show

Grand Rapids, Michigan, May 5, 6, 7

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TUESDAY, MAY 4

Open House (5:30–8:30)—Sponsored by Great Lakes Section and National Society _____ No charge

WEDNESDAY, MAY 5

( ) F.P.R.S. Luncheon _____ $ 2.65 _____

Plant Trips: Trips are being scheduled to the following firms for both Wednesday morning and afternoon. Please indicate choice and whether morning or afternoon. Trips will be approximately 2½ hours.

	A.M.	P.M.
( ) American Seating Company	____	____
( ) Grand Rapids Varnish Corporation	____	____
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THURSDAY, MAY 6

Paul Bunyan Hour—Sponsored by Supplying Companies to the Forest Products Industries _____ No Charge

F.P.R.S. Party—includes Dinner, Floor Show and Dancing

( ) Individual _____ $ 5.00 _____

( ) Couple _____ 9.00 _____

FRIDAY, MAY 7

(Technical Program continued—no event except Ladies' Program)

Ladies' Program: A complete Ladies' Program (see accompanying brochure) is being planned.

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( ) Ladies' Registration, including exclusive visits to furniture display rooms, brunch and style show, bus trip to Holland, including luncheon _____ $ 7.50 _____

Add Total _____ _____

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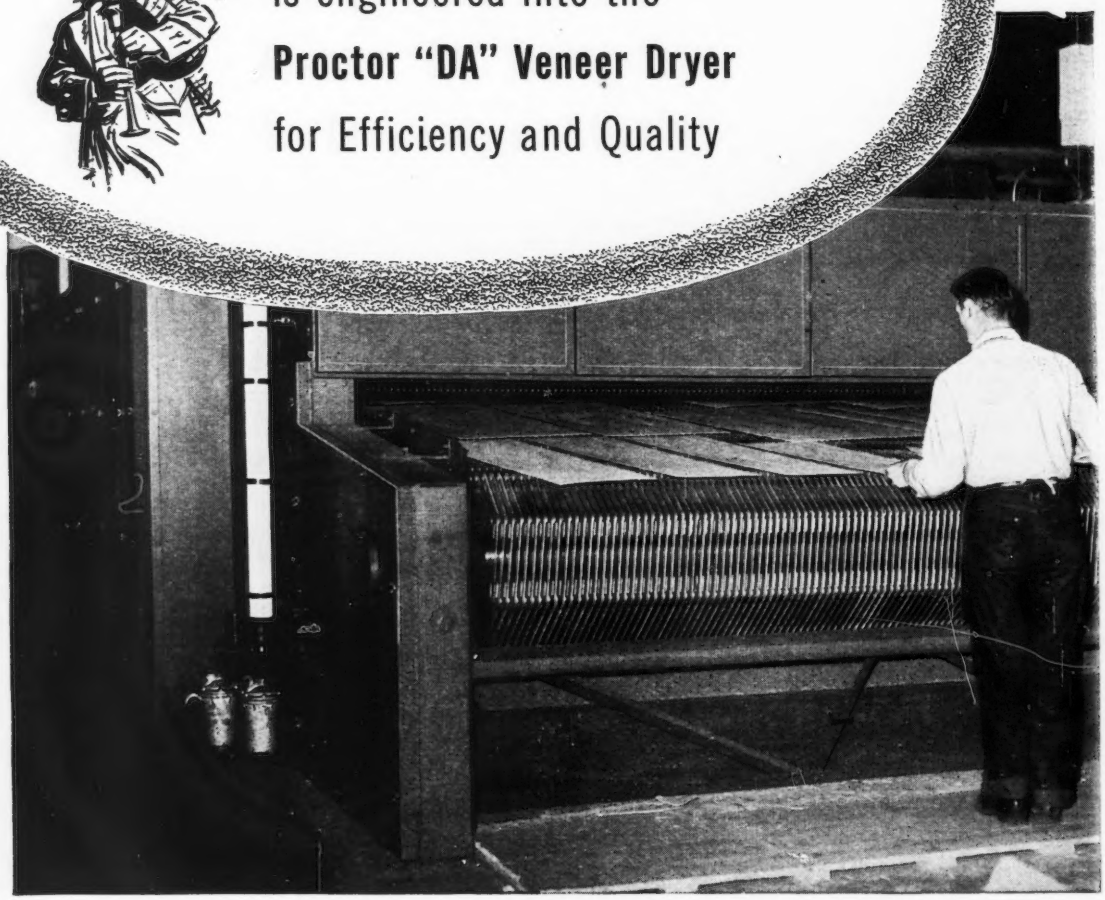

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JOURNAL OF THE FOREST PRODUCTS RESEARCH SOCIETY

Vol. IV, No. 1 February, 1954

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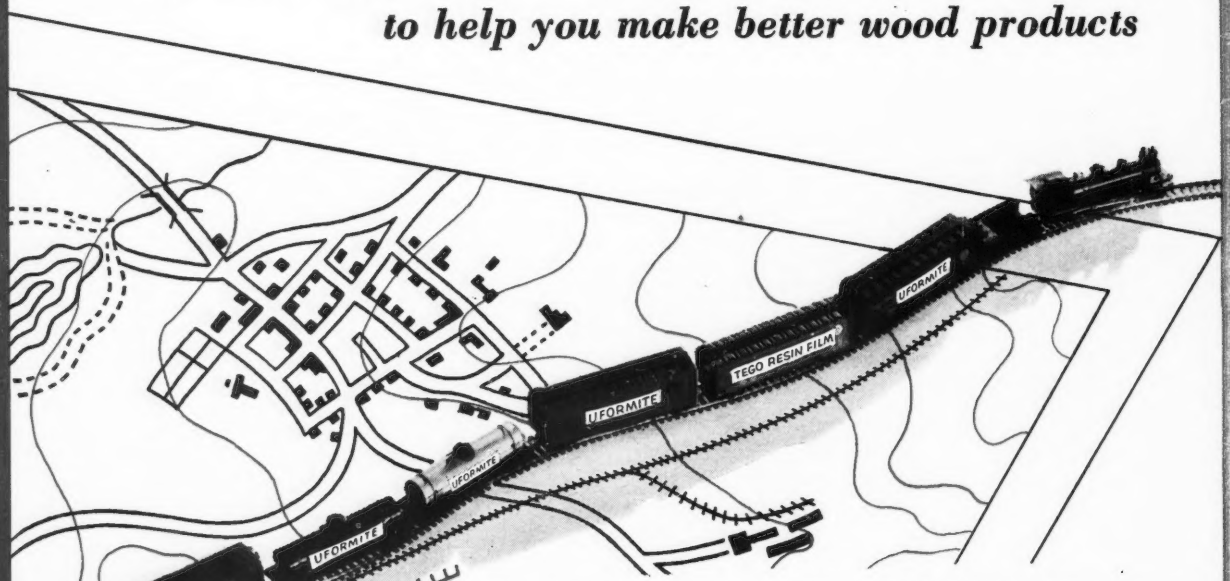
DEPENDABLE ADHESIVES . . .

to help you make better wood products



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NEWS BRIEFS

Candidates Are Announced for the FPRS 1954–55 National Offices

The National and Regional FPRS Nominating Committees have announced their slate of candidates for national offices, to be voted on by mail ballot and elected at the Annual Business Meeting to be held during the Eighth National Meeting of the Forest Products Research Society at Grand Rapids, Michigan, May 5, 6, and 7.

In the office of FPRS President for 1954–55, Lester J. Carr, L. J. Carr Lumber Co., Sacramento, Calif., will automatically succeed Robert D. Pauley, Weyerhaeuser Timber Co., Tacoma, Washington, who will remain on the Executive Board as Past-President. Mr. Carr is currently FPRS President-Elect.

The following men will be on the ballots and voted upon for:

President-Elect—Moss B. Christian, Chicago Mill & Lumber Co., Tallulah, La. Mr. Christian is currently FPRS Vice-President.

Vice-President—Ralph H. Bescher, Koppers Co., Inc., Pittsburgh, Pa. Mr. Bescher is a past North-Central Regional Board Member.

Northwest Regional Board Member—John D. Ritchie, Douglas Fir Ply-

(Continued on page 24A)

IMPORTANT FPRS DATES

April 23, 1954: Northern California Section Meeting at San Francisco.

April 29–30, 1954: Northeast Section Meeting at Williamsport, Pa.

MAY 5–6–7, 1954: NATIONAL ANNUAL MEETING at Grand Rapids, Mich.

Late May or early June: Pacific Northwest Section Meeting at Aberdeen, Wash.

May 24, 1954: Pacific Southwest Section Meeting at Los Angeles, Calif.

June 3–4, 1954: Florida–Georgia–Alabama Section Meeting held jointly with the Carolinas–Chesapeake Section at Myrtle Beach, S. C.

Late June: Carolinas–Chesapeake Section Meeting at Teco, Washington, D. C.

October: Carolinas–Chesapeake Section Meeting at Asheville, N. C.

The President's Column

R. D. PAULEY

My remarks are directed to the men in the wood industry — all of the men who wish to make new or renew industry contacts and to obtain up to date technical information on the manufacture and sale of wood products. I would like to urge you to attend our 8th Annual Meeting at Grand Rapids, Michigan, on May 5, 6, and 7. You do not have to be an FPRS member to attend our meeting; anyone interested in wood products is welcome, and I can promise you that the time you spend will be well worthwhile.

During this three-day meeting there are eight technical sessions scheduled, with a total of 40 papers on a variety of specialized subjects concerning the forest products industry. Each paper will present new information which has not previously been published. Thirteen subject matter committees will discuss in detail the problems confronting the various segments of our industry. In addition to the technical sessions and the subject matter committee meetings, there will be instructive field trips and informal sessions where you can discuss your interests with other well-known men in the wood products field.

In the same auditorium where all FPRS technical sessions and meetings are held you can visit the 1954 Wood Workers Industry Show. This show will bring together more than 100 exhibits of the newest and best in machinery and supplies—much of it in operation. Since the war there have been numerous important improvements in all types of wood working machinery. If you are thinking in terms of cutting costs, producing improved products at a faster production rate, and of meeting competition squarely, then you want to attend the Industry Show to see what each exhibitor has to offer.

In addition to the FPRS technical program and the Industry Show, the official FPRS luncheon will feature a guest speaker of national reputation. The traditional Paul Bunyan Hour, for the enjoyment of registrants, exhibitors and their guests, will be sponsored by over fifty well-known suppliers of equpiment and raw materials used by the wood products industry. The arrangements committee for the annual meeting has also planned a full and interesting program for the ladies, so be sure to bring your family with you.

You will find many of the details of the FPRS 8th Annual Meeting program elsewhere in this issue of the Journal. If you are an FPRS member, you have already received a pre-registration form. Please fill it out at once and mail it to the executive office as we expect an attendance of 700 to 1,000. It would also be well to make your hotel reservations early.

Let me emphasize that the purpose and objective in having the FPRS annual meeting is to provide a meeting place where men interested in wood products can get together and discuss ways and means to improve our industry. Those of you who have attended previous FPRS annual meetings will agree with me that the men who attend come for a purpose. They come to attend each technical session and they stay until the end because they obtain valuable information which is useful in conducting their business. The time you spend at Grand Rapids will be well invested.

Highlights of the Eighth FPRS National Meeting, in Cooperation with the Woodworkers' Industry Show

Dates—MAY 5, 6, and 7.

Place—Civic Auditorium, Grand Rapids, Michigan.

Registration—$6.00 for FPRS members, $10.00 for non-members; Ladies, $7.50.

May 5—Subject Matter Committee Meetings, Plant Tours, Woodworkers' Industry Show.

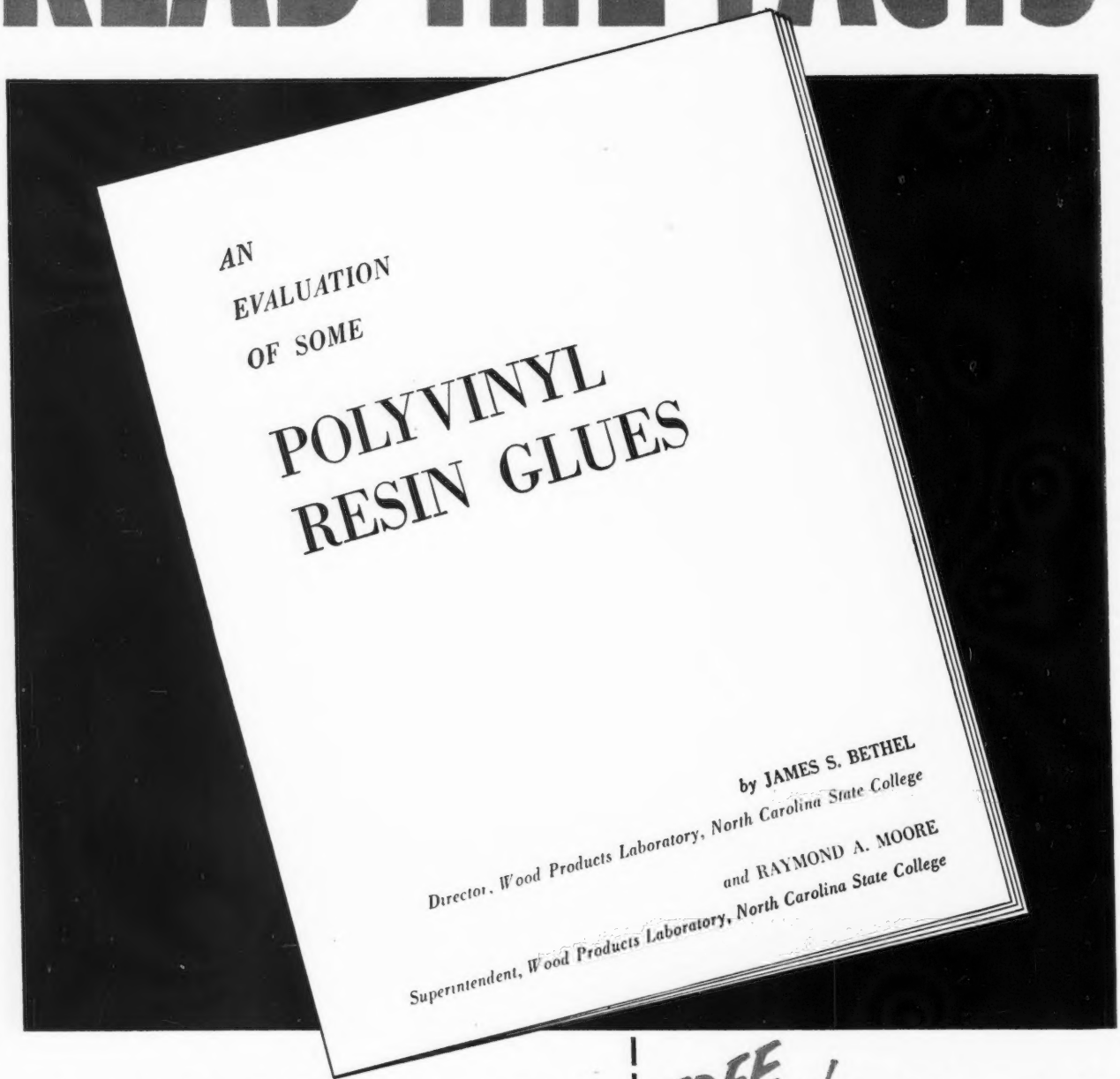
May 6—Technical Sessions: Packaging, Wood Composition Board, Wood Machining, Wood Drying. Paul Bunyan Hour—Reception and FPRS "Party".

May 7—Technical Sessions: Glues and Gluing, General, Wood Finishing, Quality Control. Official Luncheon and Business Meeting.

The ladies program will include varied activities on all three days of the meeting.

For additional details, write Forest Products Research Society, Box 2010, University Station, Madison 5, Wis.

READ THE FACTS



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Therefore, we decided to dispel some of the doubts still surrounding polyvinyl assembly glues.

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What We Need—More Product Development

PHIL CREDEN[1]
Edward Hines Lumber Co., Chicago, Ill.

MANY YEARS AGO, a philosopher, whose name is lost in antiquity, stated this truism concerning business success: "Build a better mousetrap and the world will beat a path to your door". This old adage has been quoted many times; and, in the last generation, has been so used by marketing and advertising men, that it has come to be descriptive of companies who built a good product but failed to let the world know about it, with the result that they went out of business or remained small and insignificant in the present day scheme of things where everything seems to be pointed to high powered salesmanship and high powered advertising. Most of us can recall many promotional advertisements which carried this old chestnut of a headline: "Yes, they built a better mousetrap—but failed to advertise and sell!"

It's time now, however, that the better mousetrap story be revived, especially by the wood industries, for there seems to be a prevalent feeling among too many people in our industry that all wood needs to regain its rightful position in the national market place is advertising. These people have seen the progress made by metals and plastics and are attributing the success of these new industries wholly to good selling, good publicity and good advertising. Now, we won't argue the point that wood products need all the power of effective, modern marketing technics to win back old customers and make new ones, but to go ahead and do promotion without first improving the product is getting the cart before the horse.

It is time that we took a long and thoroughly objective look at ourselves for where wood has lost markets—it was not because of lack of selling or advertising but simply because it failed to give satisfaction, or failed to keep pace with the needs of the times. No amount of advertising or good selling can overcome the deficiencies of a product. Just so that we can understand this statement, let's take the standard wood storm sash as an example. Here's a product that once enjoyed a large market—in fact, wood storm sash had all the market plus complete distribution through jobbers and lumber dealers. It was relatively inexpensive—furthermore, storm sash paid for themselves with fuel savings; in addition, they made homes more comfortable and healthful. Most wood storm sash were well manufactured from kiln-dried lumber. In the last few years, enterprising manufacturers treated their sash with water repellent, rot proofing solutions; they replaced old fashioned putty with elastic glazing compounds.

But standard storm sash are cumbersome and hard to handle—they required large storage facilities. Besides, times were changing! With the almost complete disappearance of the villege handyman, the fellow who would take odd jobs, home owners found that every Fall and every Spring it was up to them to wrestle with heavy sash. Many of them got to be thoroughly sick of job. Into this situation, smart marketing men of the metals industry walked; to be greeted with open arms by thousands and thousands of home owners. They had a product. Once it was applied to a window, there was no need for a home owner to bother about storm sash and screens any more. The unit was self storing. All he had to do in the Fall was to slip down the glass section and in the Spring, to raise it and pull down the screen. It was easy to work and entirely eliminated the drudgery and danger of putting up and taking down old-fashioned, heavy wood storm sash.

Now, the results of this new competition are apparent everywhere. Any smart marketing man could have foretold that eventually, the combination metal storm sash and screen unit would begin to replace the old wood sash. What have we, the wood industries, done about it? As far as I know, there has been only one company who tackled the problem and made a success of a wood combination unit. The rest of the industry has sat idly by and allowed this large market to slip through their fingers.

In case after case, where wood has been replaced by competitive materials, we find the same story. Analysis shows that metal has made its greatest strides against poor wood products—products that were old fashioned in styling or products that failed to live up to modern requirements. Advertising and selling, in each instance, would not have retained the market for wood. What was necessary and is still necessary today is more product improvement. We need better design, more research, newer and more efficient methods of manufacture, all pointed to making a product that will compete in the market place from the standpoint of styling, durability and usefulness. Price is a factor of small importance as against the other attributes.

The job of the Marketing Committee of the Forest Products Research Society is to bring into the limelight, the need for more product improvements. Members of the Society have contributed a great deal to the utilization of our forest resources through the development of wood by-products. Work is needed now on products coming out of the saw log, if the industry is to march into the future economically healthy, for the biggest requirement of sustained yield is sustained markets.

There are many things that can be done to advance our industry through improved selling, publicity and advertising methods. Before we can get to this, let's get back to the better mousetrap. After all, consumer satisfaction in the final analysis is going to determine whether wood holds its place as a major raw material or falls back into the limbo of forgottten things.

[1]Mr. Creden is Chairman of the newly formed FPRS Subject Matter Committee on Marketing.

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VEGETABLE
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ESTABLISHED 1899

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Chemical Composition of Gum Turpentines of Pines of the United States and Canada[1,2]

N. T. MIROV

Institute of Forest Genetics, a branch of the California Forest and Range Experiment Station[3]

Turpentine composition of all but two American pines growing north of the Mexican border is presented in a tabular form. The tabulation is preceded by a brief critical review of the present status of our knowledge of the subject. There are some 40 species of pines in the United States and Canada; 8 are common to both countries. The actual number depends on the individual attitude of an investigator in recognizing or not recognizing certain pines as independent species. The two pines whose turpentines have not as yet been investigated are *Pinus arizonica* and *P. remorata*. The former is generally considered to be a variety of *P. ponderosa*; it grows chiefly in Mexico; the latter is found on the islands off the coast of California.

History

OF THE FORTY-ONE pine species whose turpentine chemistry is reviewed here, several had been investigated by previous workers. Herty and his assistants reported chemical composition of turpentines of several southeastern pines. Surprisingly enough, their reports are not always reliable. In this paper, analysis of only one species, *P. serotina,* is credited to Herty and Dickson (9), but even in this case the information is not complete. In 1913 Schorger published "An examination of the oleoresins of [six] western pines" (24), in which he reported results of analyses of oleoresin samples collected in 1911 by the U. S. Forest Service. These data, together with data presented in two articles published by him elsewhere (25, 26), were combined and published in 1919 as a part of his "Contribution to the chemistry of American conifers" (27).

Schorger's findings may be considered as a real contribution to the knowledge of American turpentines, especially because he pointed out the specificity of turpentines and suggested that more attention be paid to the source of the product. He stimulated interest in the subject and clarified many ambiguous points, such as the occurrence of paraffine hydrocarbons instead of terpenes in two California pines. Unfortunately, in those days the methods of fractional distillation were rather primitive; Schorger used, in his fractionation of the turpentine samples, a plain 12-inch distilling tube, known as the Hempel column, a very inefficient instrument for separation of terpenes. Moreover, one of the most important terpenes—delta-3-carene had not yet been described at the time of Schorger's investigations. This terpene was discovered by Simonsen (29) in India in 1920. Schorger, thus, was unaware of delta-3-carene in ponderosa pine turpentine and reported it as limonene.

All in all, results for 6 species previously investigated have been unconditionally accepted in this paper.

In the late 1920's, the present writer conceived an idea of a systematic investigation to learn how different terpenes are distributed among the species of the genus *Pinus*. The first article on the subject was published in 1929, jointly with P. A. Foote, now the Dean of the School of Pharmacy, University of Florida. Then, after a long interval, in 1947 the author invited Professor A. J. Haagen–Smit of the California Institute of Technology to cooperate with him in the project. During the three ensuing years of this cooperative work, turpentines of 17 pine species were analyzed. Later, assistance has been rendered to the author by the University of California and by the Rockefeller Foundation. At present, the project is concerned mainly with Mexican pines, and with a study of chemical composition of turpentines in hybrids, a subject which is beyond the scope of this paper. The purpose of this article is to report on our present knowledge of North American turpentines. Some of them might be of interest as possible new forest products.

Technique of Turpentine Distillation

Oleoresin is obtained from pine sapwood by wounding the trunk of a tree. The turpentine is separated either by steam distillation, which is the commercial practice, or by heating the oleoresin under reduced pressure.

In the early investigations by Schorger (24), the turpentine was separated from the oleoresin by means of steam distillation. This method is not satisfactory for laboratory use because the high-boiling volatile ingredients, such as oxygenated sesquiterpene compounds or diterpenes, cannot be fully removed from the pot; these substances render the rosin soft, and at the same time the turpentine lacks the high-boiling components. A good example of the difficulties encountered may be seen in the turpentine of lodgepole pine *(Pinus murrayana* or *P. contorta* var. *latifolia)* from the Sierra Nevada mountains of California. When steam distilled, lodgepole pine turpentine (24) is laevorotatory and the rosin is soft. When the turpentine is distilled off by heating the oleoresin under high vacuum (say, 0.1 mm. of mercury) to a temperature of 190–200° C., a great deal of viscous dextrorotatory sesquiterpene-ketone begins to boil. Thus obtained, turpentine of Sierra Nevada lodgepole pine is slightly dextrorotatory; the rosin is hard and brittle. A certain softness of ponderosa pine rosin is undoubtedly due to the presence of some high boiling components. The relative softness of steam- distilled ponderosa pine rosin is a serious drawback for its commercial use.

Only a few pine species require temperatures as high as 200° C. in order to expell all turpentine components from the oleoresin. Generally a temperature of 150–160° C., at 0.1 mm. of pressure, is sufficient, because the majority of pine species do not contain much oxygenated sesquiterpenes and only one pine has been found to contain appreciable amounts

[1] A contributed paper.

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[3] Maintained by the Forest Service, U. S. Dept. of Agriculture, in cooperation with the University of California, Berkeley.

Table 1.- Chemical Composition of Turpentines of Pines Found in Canada and in the United States

Number	Species	Reference 1/	Geographical range	Physical characteristics of turpentine: density d	index of refraction n_D	specific rotation $[\alpha]_D$ degrees	yield of turpentine percent
1	P. albicaulis Engelm. whitebark pine	(8)	Western U.S. and Canada	$.8979^{24}_{4}$	$1.4971^{20.5}$	-25.1	31
2	P. apacheca Lemm. apache pine	(20)	Arizona	$.8648^{24}_{4}$	1.4695^{24}	-41.0	not determined
3	P. aristata Engelm. bristlecone pine	(6)	Western U. S.	$.8649^{24}_{4}$	1.4656^{25}	+25.2	24
4	P.arizonica Engelm. Arizona pine	-	Arizona	-	-	-	-
5	P. attenuata Lemm. knobcone pine	(21)	California and southern Oregon	$.8520^{23}_{4}$	1.4652^{23}	+17.1	24
6	P. balfouriana Grev. and Balf. foxtail pine	(6)	Northwestern California	$.8570^{25}_{4}$	1.4643^{25}	-11.0	28
7	P. balfouriana Grev. and Balf. foxtail pine	(6)	Southeastern California	$.8612^{25}_{4}$	1.4642^{25}	+24.3	25
8	P. banksiana Lamb. jack pine	(7)	Northeastern U. S., E. Canada	$.8525^{25}_{4}$	1.4670^{25}	+9.7	21
9	P. caribaea Morelet slash pine	(2)	Southeastern U. S.	$.8553^{25}_{4}$	1.4631^{25}	-30.7	About 20-22
10	P. cembroides Zucc. Mexican pinyon	(16)	Southwestern U. S.	$.8471^{22}_{4}$	1.4680^{21}	+45.2	26
11	P. chihuahua Engelm. Chihuahua pine	(21)	Arizona	$.8646^{24}_{4}$	1.4668^{28}	-22.0	20
12	P. clausa (Chapm.) Vasey sand pine	(25)	West Florida and Alabama	$.8724^{15}_{15}$	1.4767^{15}	-22.6	19
13	P. contorta Dougl. shore pine (Calif.) lodgepole pine	(18)	Alaska, W. Canada, Pacific Coast of U.S. This sample from British Columbia.	$.8452^{25}_{4}$	1.4828^{25}	-17.3	15
14	P. coulteri D. Don Coulter pine	(13)	California, Lower California.	$.8505^{25}_{15}$	1.4767^{25}	-15.2	17
15	P. echinata Mill. shortleaf pine	(15)	Southeastern U. S.	$.8575^{20}_{4}$	1.4685^{23}	+ 9.9	24
16	P. edulis Engelm. pinyon pine	(24)	Colo., W. Okla., W. Texas, Utah, Ariz., New Mexico, Lower California.	$.8680^{15}_{15}$	1.4717^{15}	+22.0	20
17	P. elliottii var. densa Little & Dorman slash pine	(12)	Florida	$.8472^{31.8}_{4}$	1.4720^{20}	-33.0	19
18	P. flexilis James limber pine	(6)	South Dakota, Nebraska westward; from Montana to Texas. This sample from White Mts., Calif.	$.8606^{29}_{4}$	1.4707	+41.2	20
19	P. glabra Walt. spruce pine	(19)	Southeastern U. S.	$.8599^{23}_{4}$	1.4735^{23}	-4.6	22
20	P. jeffreyi Grev. and Balf. Jeffrey pine	(26)	S. Oregon, W. Nevada, California, and Lower California.	.6951 to $.7110^{15}_{15}$	1.3927 to 1.4065^{15}	±0.0	about 10
21	P. lambertiana Dougl. sugar pine	(22,24)	So. Oregon, California, W. Nevada, Lower Calif.	$.8669^{24}_{4}$	1.4753	-7.5	16-18
22	P. monophylla Torr. and Frém. singleleaf pinyon	(26)	From Utah to Calif. and Lower California	.8721 to $.8733^{15}_{15}$	1.4732 to 1.4733^{15}	+14.4 to +17.3	19
23	P. monticola Dougl. western white pine	(3,20)	Western States	$.8691^{20}_{20}$	1.4646^{23}	+20.6	18
				$.8500^{23}_{4}$	1.4687^{23}	-29.8	18-20
24	P. muricata D. Don Bishop pine	(14)	California	$.8610^{15}_{4}$	1.4693^{15}	+11.6	22.4
25	P. murrayana Grev. and Balf. lodgepole pine	(18,24)	Sierra Nevada of Calif, Rocky Mountains.	Colorado $.8473^{25}$	1.4801^{25}	-10.0	19
				California $.9013^{22}_{4}$	1.5008^{22}	+ 2.4	26

Chemical composition of turpentine percent	Remarks
Δ^3carene 32; α-terpinyl acetate 3; cadinene 10; albicaulene[2] 42; albicaulol 0.2; cembrene 2.5[2]	High elevation pine. Of no present commercial value.
l-α-pinene 80; β-pinene 2; dipentene 2; l-longifolene 12.	Also called P. engelmannii Carr.
l- and d-α-pinene 96; a tricyclic sesquiterpene 4.	Of no present commercial value. Poorest gum-yielding pine.
Composition of turpentine yet unknown.	Considered by some as a variety of P. ponderosa.
l-α-pinene 98.	Species of purest α-pinene.
dl- and d-α-pinene 90; β-pinene 2; limonene 2; a tricyclic sesquiterpene 4.	Rare mountain pine.
dl- and d-α-pinene 96; bornyl acetate 1; tricyclic sesquiterpene 1.	Rare mountain pine.
dl- and d-α-pinene 85; β-pinene 10.	
l-α-pinene about 75; β-pinene about 20; cadinene 3.	Name recently changed (12) to P. elliottii. A source of commercial turpentine. Turpentine of this pine from Nicaragua has different composition (10).
d-α-pinene 92; dl, l-limonene 4; l-longifolene 2.	Grows chiefly in Mexico.
l-α-pinene 50; β-pinene 20; limonene 20.	Grows chiefly in Mexico. Considered by some as a variety of P. leiophylla.
l-α-pinene 10; β-pinene 75; camphene 10.	
Trace of l-α-pinene and β-pinene; l-β-phellandrene 98+.	Crosses naturally with P. banksiana; considered by some same as P. murrayana.
l-α-pinene 30-35; l-β-phelandrene 35-45; n-undecane 10; n-heptane 5.	Naturally crosses with P. jeffreyi.
d-α-pinene 85; β-pinene 11.	
d-α-pinene 70-75; β-pinene 5; sesquiterpene fraction (reported as cadinene) 15-20.	Apparently crosses in field with P. monophylla (singleleaf pinyon).
Not known as yet	Physical characters determined by Naval Stores Sta. Olustee, Fla. For recent taxonomic change see (12).
dl- and d-α-pinene 80; albicaulene[2] 13; a bicyclic sesquiterpene 7.	Should be thoroughly investigated. Apparently crosses naturally with P. monticola and P. reflexa.
d-α-pinene 45; β-pinene 45; limonene 8; sesquiterpene 1.	
n-heptane 95; normal octyl, nonyl and (chiefly) decyl aldehydes.	Naturally crosses with P. ponderosa and P. coulteri. Good yielder of oleoresin. Has been used for commercial production of heptane.
l-α-pinene 65; β-pinene 13, a bicyclic sesquiterpene 10; sesquiterpene alcohol 2.	Needs further investigation.
d-α-pinene 85; limonene 4-5; sesquiterpene fraction reported as cadinene 4-6.	Apparently crosses naturally with other pinyon pines.
Sample from NE California: d-α-pinene 66; β-pinene 26; n-undecane 1-2; unidentified sesquiterpene.	
Sample from northern Idaho: n-heptane less than 1; l, dl- α-pinene 45; β-pinene 32; l-limonene 7; n-undecane 2; bornyl acetate 2; sesquiterpenes 4-5.	
l-α-pinene 98; camphene less than 1.	More work should be done with N. and S. forms of this species.
Sesquiterpene-ketone (10% in California sample, very little in Colorado sample; α-pinene traces; l-β-phellandrene 90.	More work should be done with this pine throughout its range. This pine sometimes called P. contorta var. latifolia Engelm.

of high-boiling diterpenes. The criterion of a complete removal of the volatile part is the hardness of the pot residue, i. e. of the rosin.

Components of Pine Turpentines

Terpenes ($C_{10}H_{16}$) are cyclic, unsaturated hydrocarbons composed of two isoprene units C_5H_8.

The turpentines of most American pines consist chiefly of two bicyclic terpenes: alpha- and beta-pinenes. Alpha-pinene may appear either as a dextro- or as a laevo-form. Beta-pinene of American pines is always in its laevo-form. Of the other bicyclic terpenes there are found: delta-3-carene and (rarely) camphene (in *P. clausa* and *P. muricata)*.

Delta-3-carene is a recently discovered and still little-known terpene. It is found in Scotch pine of Eurasia and in two or three southeastern Asiatic pines (3). Its abundance in all studied varieties of ponderosa pine perhaps would render this rather reactive terpene an important commercial raw material. In the past the users of ponderosa pine turpentine were reluctant to accept it as a genuine product, because it possessed the pleasantly sweet odor of delta-3-carene, quite different from the odor of commercial turpentine. Moreover, specifications for commercial turpentine are written for a mixture of alpha-pinene (B.P. 155° C.) and beta-pinene (B.P. 165° C.); whereas delta-3-carene boils at 172° C.

Monocyclic terpenes are rare: laevo-beta-phellandrene is found in two, perhaps three, species. Lodgepole pine turpentine of the Pacific Coast and of the Rockies is almost pure l-beta-phellandrene. Phellandrene may have some commercial possibilities. Lodgepole pine occupies an enormous area in western North America. In the Canadian Rockies the yield of oleoresin of lodgepole pine is poor, but perhaps nearer the coast and farther south yields might be better. (It would be interesting to experiment with obtaining phellandrene by steam distillation of lodgepole pine stumpwood.)

Another monocyclic terpene, limonene, is found—always in its laevorotatory modification (to be exact, generally in its dl-l- form)—in small amounts in several pines. A large percentage of l-limonene occurs in turpentines of *P. serotina* and *P. torreyana.* The third monocyclic terpene, terpinolene, occurs in a small quantity in varieties of ponderosa pine and in the "Mexican white pine" *(P. reflexa)* of Arizona.

Paraffin hydrocarbons—heptane and undecane—are present in the turpentines of several American and Mexican pines. Two California species—

Table I.- Continued

26	P. palustris Mill. longleaf pine	(1,2)	Southeastern U. S.	$.8618^{25}_{4}$	1.4657^{25}	+7.9	About 20-22
27	P. parryana Engelm. Parry pinyon	(10)	California, Lower California	$.8659^{23.5}_{4}$	1.4742^{24}	+24.8	23
28	P. ponderosa Laws. ponderosa pine	(7,18)	Western States from S.Dakota to Calif. from B.C. to Ariz. This sample from California.	$.8594^{22}$	1.4765^{23}		15
29	P. ponderosa	(15)	From Utah.	$.8611^{23}_{4}$	1.4720^{24}	+27.0 to -20.0	26
30	P. ponderosa	(11)	From Arizona	$.8701^{22.5}_{4}$	1.4730^{23}	+13.7	22
31	P. ponderosa	(11)	From Colorado	$.8648^{23}_{4}$	1.4761^{23}	+1.2	20
32	P. ponderosa	(11)	From South Dakota	$.8692^{23}_{4}$	$1.4781^{22.5}$	-2.1	19
33	P. ponderosa	(11)	From N. Idaho	$.8601^{22}_{4}$	1.4763^{20}	-2.7	22
34	P. pungens Lamb. Table-Mountain pine	(19)	Southeastern U.S.	$.8564^{23}$	1.4682^{23}	-23.7	14 (low because of accident.)
35	P. radiata D. Don Monterey pine	(23)	California	$.8596^{23}$	1.4727^{22}	-5.8	
36	P. reflexa (Engelm.) Engelm. Mexican white pine	(17)	Southwestern U.S.	$.8456^{24}$	1.4669^{22}	±0.0	16
37	P. remorata Mason Santa Cruz Island pine	-	Island near California Does not occur on the continent.	-	-	-	-
38	P. resinosa Ait. red pine	(17)	Eastern Canada and U. S., south to W. Virginia.	$.8571^{23}$	1.4668^{23}	+10.0	20
39	P. rigida Mill. pitch pine	(15)	Eastern states from Maine to Georgia.	$.8560^{20}$	1.4701^{23}	-9.0	23
40	P. sabiniana Dougl. Digger pine	(24)	California	$.6971^{15}_{15}$	1.3903^{15}	0.0	About 10
41	P. serotina Michx. pond pine	(9)	Southeastern U. S.	$.8478^{20}$	1.4734^{20}	-105.5	About 20
42	P. strobiformis Engelm. Mexican white pine	(18)	Southwestern U. S.	- -	-	See P. reflexa	- -
43	P. strobus L. eastern white pine	(23)	Eastern Canada and United States	$.8611^{21}_{4}$	$1.4714^{20.5}$	-0.7	25
44	P. taeda L. loblolly pine	(23)	Southeastern U. S.	$.8570^{22}$	$1.4675^{27.5}$	+20.2	19
45	P. torreyana Parry Torrey pine	(5)	Southern California	.8366 to $.8355^{23.5}$	1.4660 to 1.4650^{25}	-121.9 to -115.5	17
46	P. virginiana Mill. Virginia pine	(23)	Southeastern U. S.	$.8563^{26}$	$1.4657^{22.5}$	-3.83	23
47	P. washoensis Mason & Stockwell	(7)	Western Nevada	.8522 to $.8613^{23}$	1.4744 to $1.4777^{21.5}$	-9.7 to +8.4	About 20

1/ Numbers in parenthesis refer to the literature cited a the end of article.

2/ A monocyclic sesquiterpene with 3 double bonds.

3/ A diterpene with one ring and 4 double bonds.

4/ Physical characters of 19 individual trees were examined.

-α-pinene about 60; β-pinene 32; .07 heads; 0.7 tailings.	Source of American commercial turpentine.
-α-pinene 60 to 65; sesquiterpene fraction 20; ocimene.	Possibly crosses naturally with other pinyon pines. Might be of commercial importance. More work needed. Also called P. quadrifolia Parl.*
-α-pinene less than 1; β-pinene 50; Δ^3-carene 30; limonene 3-4; sesquiterpene fraction 10, incl. cadinene and a tricyclic sesquiterpene.	Content of limonene (25%) and absence of α-pinene in (7) proved to be erroneous.
dl-α-pinene 45; Δ^3-carene 40; limonene 2-3; longifolene 10.	α-pinene might have been overlooked. If present, only in very small quantity.
dl-α-pinene 34; β-pinene 14; Δ^3-carene 31; l-limonene 4; longifolene 4; an unidentified sesquiterpene 4-5.	
dl-α-pinene 2-3; β-pinene 30; Δ^3-carene 47; terpinolene 2-3; methyl chavicol 1; longifolene 8; cadinene 1.	
dl-α-pinene 2; β-pinene 38; Δ^3-carene 37; terpinolene 3; methyl chavicol 1-2; longifolene 13.	
dl-α-pinene 1-2; β-pinene 12; β-myrcene 5; Δ^3-carene 69; l-limonene 5; methyl chavicol 2; sesquiterpenes (partly cadinene)	Contains very large amounts of Δ^3-carene.
dl-l-α-pinene 70; β-pinene 20; limonene 10.	
dl-α-pinene 75; β-pinene 22.	Sample from France: -11.3° " " Crimea: -3.4° " " New Zealand: -12.4°
dl-α-pinene 75; Δ^3-carene 5; d-terpinolene 5; n-heptane 5; n-undecane 2-3; cadinene 5.	Often designated as P. strobiformis; apparently crosses with P. ayacahuite. Also called P. flexilis var. reflexa Engelm.
Composition of turpentine yet unknown. The turpentine is laevo-rotatory	Taxonomic status of this pine as yet uncertain.
dl- and d-α-pinene 92; β-pinene 3; phellandrene (?) 3; and about 1% of a dextrorotatory high boiling component.	Needs a thorough study.
l-α-pinene 65; β-pinene 20; limonene 10.	
n-heptane 95; small amounts of aliphatic aldehydes, mostly n-decyl.	Poor yielder of oleoresin.
limonene 80-90	Data incomplete. Needs an additional study.
- - - -	For nomenclature consult (17)
dl-α-pinene 75; β-pinene 15; oxygenated terpene derivatives (alcohols, ketones?) 4; tricyclic sesquiterpene less than 1%	
d-α-pinene 85; β-pinene 12.	
limonene 75; decyl aldehyde 10; n-undecene 5; longifolene 4; minute quantities of n-heptane; n-nonane, etc.	Turpentine of this pine cannot be obtained commercially.
dl- and l-α-pinene 98; (dl-α 90; l-α 8).	
Varying amounts of Δ^3-carene and β-pinene in individual trees. All trees contain small quantities of α-pinene, dl-limonene and unidentified sesquiterpene.4/	Apparently an intraspecific hybrid or a mutant of P. ponderosa. Rare, of no present commercial value.

Digger pine *(P. sabiniana)* and Jeffrey pine *(P. jeffreyi)*—still remain the best source of normal heptane. This hydrocarbon was once obtained commercially from Jeffrey pine for testing motor fuels. With little effort it can be made in a chemically pure form. Undecane occurs in turpentines in very small quantities. An aliphatic terpene, myrcene, has been found in one variety of ponderosa pine. Another aliphatic terpene, ocimene has been identified in our laboratory in the turpentine of *P. parryana.*

Sesquiterpenes (i. e., terpenes made up of three isoprene units and accordingly having an imperical formula $C_{15}H_{24}$) occur in pine turpentines generally in small quantity and are mostly only of a scientific interest. More sesquiterpenes are found among the white pines than the hard pines. Whitebark pine *(P. albicaulis)* contains over 50 percent of sequiterpenes. Of possible practical interest is the occurrence in the pinyon pines of a sesquiterpene, characterized by a crystalline derivative, cadinene hydrochloride*. Pinyon sesquiterpenes appear to be useful perfume chemicals, as fixatives, and they can be obtained in large quantities from the pinyon of Utah–Colorado *(P. edulis)* and from the Parry pinyon *(P. parryana)* of southern California. The latter, perhaps, is the better source. Mexican pinyon *(P. cembroides)* does not contain cadinene-like sequiterpenes, but does contain a sesquiterpene, longifolene, originally discovered in *Pinus longifolia* of India (29), and proved in the course of present investigations to be the most common sesquiterpene of American pines. The customary lumping of all four pinyons (Nos. 10, 16, 22, and 26 of Table I) into one species (28), *Pinus cembroides,* might be embarrassing for a person who planned to make cadinene-like sesquiterpenes from pinyon turpentine. From Parry pinyon (No. 26), he would get plenty; from the Mexican pinyon (No. 10), none.

Aliphatic aldehydes (mostly decyl aldehyde) are found in small amounts in three American pines: *P. sabiniana, P. jeffreyi* and *P. torreyana.* The sweet vanilla-like odor of Jeffrey pine "balsam" is not due to vanillin as some suppose, but to octyl, nonyl, and decyl aldehydes. The aldehydes of Jeffrey pine and Digger pines have been thoroughly studied by Foote (3) and by Uhl (30), respectively. Apparently, P. coulteri also contains decyl aldehyde (18).

Other oxygenated terpene compounds, that is, alcohols, esters, ketones, are extremely rare in American turpentines. The sweet smell of turpentine from whitebark pine is due, at least partly, to the presence of alpha-terpenyl acetate. Traces of bornyl acetate are found in *P. balfouriana* turpentine. There are small amounts of unidentified terpene alcohols and ketones in the turpentine of the Eastern white pine *(P. strobus).* Methyl chavicol was discovered in our laboratory by P. M. Iloff, Jr., in the gum turpentines of several chemical varieties of ponderosa pine. Sesquiterpene alcohols also are rare in American turpentines.

* Several sesquiterpenes of different structural formula will yield cadinene hydrochloride.

As was already mentioned, a sesquiterpene ketone has been found in our laboratory (by P. M. Iloff, Jr.) in the turpentine of *Pinus murrayana (P. contorta* var. *latifolia)*.

A diterpene ($C_{20}H_{32}$ has been detected only in *Pinus albicaulis* turpentine. It appears, however, that small quantities of diterpenes may be present in turpentines of several pines. Ponderosa pine apparently contains small amounts of either diterpenes or some oxygenated sequiterpene derivatives.

The heads and tails of any turpentines may contain minute quantities of various compounds. Chadwick and Palkin (1) analyzed the heads and tails by distilling large quantities of commercial turpentine of *Pinus palustris*. They found that only 0.07 percent of turpentine distilled below alpha-pinene (155° C.), but were unable to identify any components. In the tailings they found minute quantities of: an unsaturated hydrocarbon (p-menthone?), dipentene, terpinolene, methyl chavicol, bornyl acetate, terpene alcohols, hydroxy compounds (part of them phenolic), etc. At least some of these compounds are, no doubt, of a secondary origin, but some of them probably occur in minute quantities even in freshly prepared turpentines.

Southeastern vs. Western Pines

Turpentines of southeastern and western pines differ greatly. The southeastern pines generally yield turpentines of a very simple chemical composition, thus resembling European pines (excepting *P. sylvestris* which apparently came to Europe from Asia). The southeastern turpentines consist mostly of a varying mixture of alpha- and beta-pinenes, except that *P. serotina* turpentine is apparently composed almost entirely of limonene. *P. pungens* and *P. glabra* have a small admixture of this terpene. There is no carene in the southeastern pines; sesquiterpenes are almost completely lacking. Most of the world supply of commercial turpentine comes from slash and longleaf pines of southeastern United States.

On the other hand, western pines often possess very complicated turpentines; there are found aliphatic hyrocarbons, aliphatic aldehydes; delta-3-carene; sesquiterpenes; such as longifolene, cadinene. The chemical composition of western pines has a great deal in common with that of pines of southeastern Asia. Some of the ingredients of the western turpentines may be of commercial importance.

Specificity of Turpentines

Each pine has its specific turpentine. *Pinus contorta* always yields turpentine consisting almost entirely of laevo-beta-phellandrene; *P. jeffreyi* turpentine always consists chiefly of n-heptane. The composition of turpentine of a pine species does not change qualitatively from one place to another; neither does it change much during the growing season; the small seasonal fluctuations are of a quantitative rather than a qualitative nature. When a turpentine consists of a mixture of two or more terpenes, individual trees may differ slightly in proportion of the components. For instance, *P. ponderosa* turpentine consists essentially of a mixture of pinenes and d-delta-3-carene. Nonetheless, the specificity of Ponderosa pine turpentine is evident in every tree, i. e. carene always will be there, but the ratio between the pinenes and the carene might be different as clearly shown by fluctuation of the optical properties of the individual samples of turpentine. Often the same terpene is found in a turpentine in two modifications: laevo- and dextro-. Different proportions of both also cause variability of the optical properties of turpentines of individual trees. Because of the variability of optical properties within a species, there are many conflicting reports on the rotatory power of different samples of turpentines of the same species of pines. The degree of variability is different in different species. In Jeffrey and Digger pines there is no variability at all because the bulk of their turpentines consists of optically inactive substances. Lodgepole pine (except its Sierra Nevada variety) whose turpentine consists almost entirely of l-beta-phellandrene, possesses a surprising uniformity of the rotatory power of its turpentines in a population of individual trees. On the other hand, in certain localities *Pinus ponderosa* populations may consist of some dextro- and some laevo-rotatory trees. The variability in turpentine composition is the subject of a future investigation.

A species occupying a large geographical range may consist of several physiological races, each having its peculiar turpentine; for instance, compositon of turpentine of ponderosa pine from South Dakota is different from the composition of ponderosa pine turpentine from Arizona. It does not mean that the *same* pine growing in the two different places has different turpentines, but rather it indicates that there are chemicaly different varieties of ponderosa pine. In studying chemistry of pine turpentines, one may expect occasionally to run across a chemical mutant. An investigator also should be aware of occurrence of hybrids, for when two pine species cross, their turpentines also cross, so that the hybrid possesses a mixed turpentine. For instance, Jeffrey × ponderosa hybrid turpentine contains a mixture of heptane and terpenes. The question of chemical composition of turpentines of hybrid pines is beyond the scope of this paper. It suffices to say that genetic laws govern the chemistry of turpentines and the mode of their inheritance in the same way as they govern the external characters of pines.

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Arabogalactan from Western Larch Wood

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Arabogalactan is a natural polysaccharide potentially available in large quantity at low price, but a simple, inexpensive process for its preparation has not been previously worked out. An easy commercial procedure involving hot water extraction, vacuum concentration and spray drying has been carried through the pilot plant stage. Rate curves have been worked out for bed-in-place extraction of coarse chips with hot water and alcohol solutions. Data on the properties of the stable product are presented. It has been shown that insulating board can be made from the extracted chips. With this process at hand, commercial development awaits a large-scale use for the material.

THE BUTT LOGS of Western larch (larix occidentalis) are usually left in the woods because they are too heavy to float, contain too much shake and so much viscid material that they gum up the saw. For some time it has been known that a relatively large percentage (4–23 percent) of these logs consist of a water-soluble carbohydrate known as arabogalactan or ϵ–galactan. This arabogalactan, despite its abundance and the ease with which it can be prepared, has as yet not been commercially produced. It is hoped that the simple inexpensive process described here will stimulate the search for large scale uses of this interesting water-soluble polysaccharide. As early as 1916, Schorger and Smith (4) described the preparation of gum from larch sawdust by extraction with boiling water. Patents issued to Schorger (3) and Acree (1) describe such processes and also the simultaneous extraction and oxidation of the carbohydrate with mucic acid as the final product. This earlier work does not consider the rate of extraction, nor is low temperature extraction considered in detail. White (6) and others (8) have studied the chemical composition of the purified water-soluble material in some detail and have shown that it is a definite chemical entity rather than a random mixture. Arabogalactan is mucilaginous in nature, grey-white to buff in color, depending on the method of preparation, and has virtually no hygroscopicity when properly dried.

Finely divided wood (commonly sawdust) has been selected for extraction by previous workers in the field in order to speed the extractive process and make the extraction as complete as possible. Most attention during this study has been focused upon chips of relatively coarse size as shown in Figure 1. These chips were made with a regular paper chipper, but because the logs used were short, there is a slightly greater amount of coarse, unchipped material than usual. Figure 1 shows the range of sizes involved, but the chips used were much more uniform than might be inferred from the photograph.

There are two reasons for this choice: (1) the grinding of wood to small dimensions is an expensive and difficult process, particularly

Figure 1.—Raw chips for extractions.

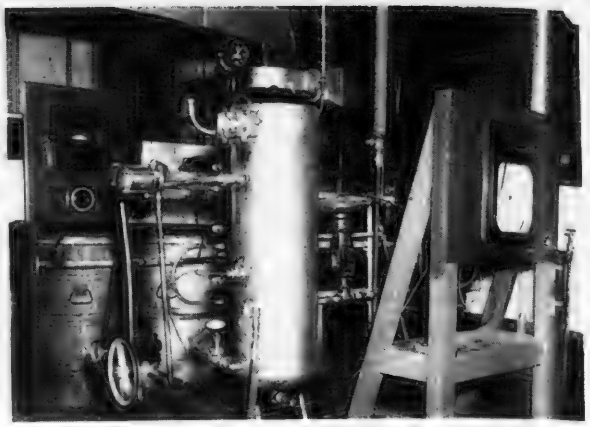

Figure 2.—Larch extraction unit.

when the wood contains as much heat-sensitive material as the larch and (2) the partly extracted chips resulting from the extraction were viewed as possible raw material for pulp or board manufacture—a procedure not feasible with sawdust or ground wood.

Experimental

Beyond the preliminary stages, extraction has been brought about in pilot plant equipment using approximately 25 lbs. of wood chips and 100 pounds of water per charge. A diagram of the unit is shown in Figure 2 and a photograph in Figure 3. All metal coming in contact with the extract being handled is either brass, copper or silver solder. Extract left in contact with brass or copper slowly discolors, so it is doubtful that these materials are the optimum ones. Over 1000 hours of use have shown the corrosion rate on the equipment to be trivial. The pump used with this apparatus has only one function—to circulate the extracting liquid to provide adequate heat control. The rate of flow of the fluid has been altered as much as ten-fold without affecting the rate of extraction.

Mitchell and Ritter (2) made an extensive survey of the distribution of arabogalactan in western larch wood and sawmill waste. They found that the gum was most plentiful in the lateral roots and that it decreased markedly in abundance as the tree was ascended. The waste butt logs, therefore, are the most desirable raw materials on which to operate an extraction plant because of their high solubles content and present low value.

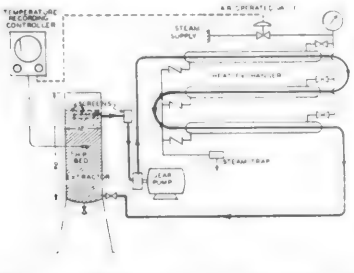

Figure 3.—Flow diagram of extraction unit.

Four butt logs approximately two feet in diameter and twenty feet long were furnished by Potlatch Forests Inc. of Potlatch, Idaho and these logs formed the raw materials on which the extractive tests were run. The amount of water-soluble material in these logs varied with both the log involved and the position in the log, but averaged 18 percent based on air-dried wood. The logs were sawed into eighteen inch lengths with a chain saw and stored indoors. Chips were prepared in batches of approximately 200 pounds by splitting the wood with an axe into pieces about four inches square, carefully debarking by hand, and feeding the resulting sticks through a small Appleton chipper. The resulting chips were rapidly screened over a 4-mesh vibrating screen to remove dirt and used as the extractor charge without further treatment (Fig. 1). When smaller chips were desired, they were made by reducing the Appleton chips, dry, in a Bauer Mill, then screening through a set of 8-inch U. S. Standard testing sieves.

Determination of the extracted solubles was made by evaporating approximately 10 gram samples to constant weight in an electric oven held at 110° C. Weighings were made to four decimal places, but no attempt was made to correct for the dissolved solids (0.02 percent) in the tap water used as the extracting agent.

Experimental Results

As would be expected with a natural material of varying constitution, extraction rates and the concentrations of the extracts obtained vary with the arabogalactan content of the wood, the temperature and the ratio of wood to water for a given size of chip. Figures 4 and 5 show typical data on the extraction of coarse chips.

Figure 6 is a composite summary of the data of Figures 4 and 5 plus a considerable amount of additional data. This generalized curve shows the range of extract concentrations which may be expected in a given time. This curve must not be used for chips of a finer or markedly coarser size than those used in this study. Finer chips will give lines above the shaded area, coarser chips lines below the shaded area and results with different temperatures do not justify any exact predictions other than within the shaded zones shown. Most runs were made with a ratio of 0.265 pounds of air dry chips to 1 pound of water. This represents the amount of water necessary to just cover the chips being extracted. Since extracts prepared above 160° F. are somewhat darker in color and have a lower pH, 160° F. appears to be the optimum temperature for extraction with water where a high quality product is desired.

For the development of a commercial extraction process, two major difficulties are presented by the foregoing procedures: (1) the rate of extraction is quite low and (2) the solutions obtained are undesirably dilute. The speed-limiting factor on the rate of extraction is undoubtably the rate of diffusion of the polysaccharide within the chip, and it should therefore be possible to increase the rate of extrac-

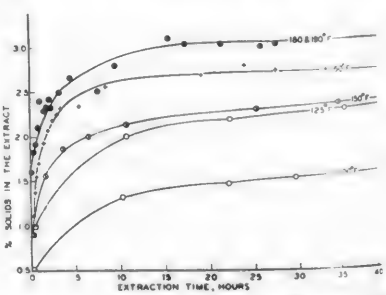

Figure 4.—Representative runs on wood of moderate Arabogalactan content.

tion markedly by decreasing the chip size provided that channeling does not offset the effect of chip size reduction. Figure 7 shows the results of experiments on smaller sized chips and establishes, within limits, that channeling is not the major factor with most of the chip sizes studied. The middle curve is anomalous to the other two, for extraction rates are slower despite reduced particle size; this requires an explanation. Wood that is Bauer ground is quite heterogeneous and forms a compact bed through which there is much channeling. This channeling results in the presence of pockets which are not provided with adequate solvent for extractive purposes. The experimental data do not show that rate may be decreased with diminishing average particle size, but rather that fine heterogeneous material is not suitable for bed-in-place extraction. Extraction with smaller sized particles was not attempted because such particles would not be suitable for pulp or board manufacture. It is believed that a combination extractive and board by-product procedure will be most likely to be commercially attractive.

A more concentrated solution as a product would lessen the evaporative load to a marked degree. Countercurrent or sequential extractions (using the liquor from one extraction to extract fresh chips) offer the most promising routes. Two runs were made at temperatures of 150 and 190° F. using three sequential 10-hour extractions with fresh chips. Terminal concentrations thus obtained are approximately twice those obtained in a single extraction. A single 10-hour extraction with fresh water and fresh chips is capable of removing around 60% of the total solubles in the wood. Three sequential extractions remove an average of only 40% of the solubles in the three samples. Sequential extraction offers little attraction, therefore, where removal of the major portion of the galactan is desired. Countercurrent extraction should improve the results obtained, but it is doubtful that investment in so much equipment is desirable when producing a low priced item. The ratio between fuel and equipment costs will determine the choice between more fuel or more equipment cost.

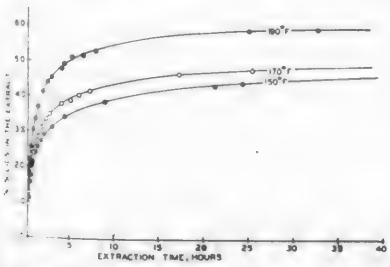

Figure 5.—Representative runs on wood of high Arabogalactan content.

Extractions were made with 0.5 and 2.0% sodium hydroxide solutions at 160° F. The syrups thus obtained were very dark red-brown, foamed persistently during concentration and had a peculiar odor of burnt sugar. It was not possible to isolate arabogalactan from this mixture.

Small scale laboratory tests showed faster rates of extraction and a small color improvement in the final product when dilute alcohol solutions replaced water as a solvent. Figure 8 shows the results of extractions at 160° F. with various concentrations of ethyl alcohol. These data are replotted in Figure 9 and show that 28% alcohol in the extracting solution should give the maximum galactan content in the extract at any time, that is, the highest rate of extraction. The arabogalactan obtained by alcoholic extraction has been found to show little or no superiority over that obtained

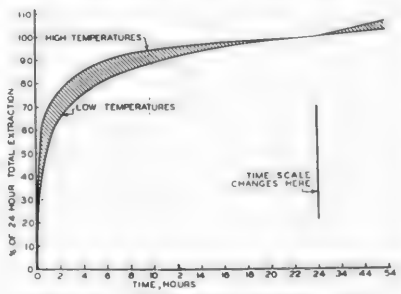

Figure 6.—Generalized extraction curve.

by water extraction and it appears probable that the expense of alcoholic extraction can not be justified.

Concentration of dilute arabogalactan liquors under atmospheric pressure is not practical, for much burning and darkening occurs. Concentration to 50% solids without noticeable discoloration is quite feasible under reduced pressure. A large number of samples have been concentrated in a small stainless steel milk evaporator under a vacuum of 22 to 24 inches of mercury using steam at 6 p.s.i. in the coils. Under these conditions the 50% solution boils at 125° F., about 2° F. boiling point elevation. Foaming is not excessive. It has not proved practical to concentrate much above 50% solids, for such solutions may burn on the heating coils and subsequent handling is complicated by a considerable increase in viscosity.

Drying of the syrup is desirable, for it is attacked by moulds. Tray drying under atmospheric pressure is slow, difficult and unsatisfactory. A thick skin on the surface slows drying, the material clings stubbornly even to glass trays and considerable

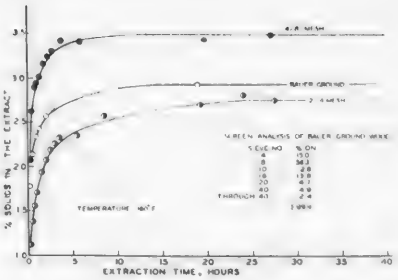

Figure 7.—Extraction of finely ground wood of moderate Arabogalactan content.

darkening occurs. It requires about 72 hours to reduce a tray containing a one-inch layer of 3% solution to dryness. A fine appearing, light and fluffy material can be obtained by lyophylization at dry ice and acetone temperature under absolute pressures of 40 to 60 microns, but this can scarcely be considered a promising commercial procedure. A 50% solution has been dried without difficulty in a small stainless steel spray dryer of the type used for producing powdered milk. Best quality material resulted when inlet air temperatures of 270–300° F. were used giving outlet air temperatures of 140–170° F. An even lighter colored material results from spray drying 3% solution. The spray dried powder is light buff to tan in color, fine, unctious, non-hygroscopic, has a bulk density of approximately 24 pounds per cubic foot and appears to be the equal of that obtained by the more expensive lyophylization. The odor is faint, pleasant and woody. The powder can be stored indefinitely at room temperature without deterioration when it contains the 3–6% normal residual moisture. The gum dissolves readily in water to yield an amber solution and might well find a place in the commercial field as a readily available domestic gum of modest price and large supply.

Attempts to discover a commercially promising procedure for improving the color of the galactan obtained have met with indifferent success. Earlier investigators have "purified" the material by repeated fractional precipitations with ethyl alcohol. Attempts

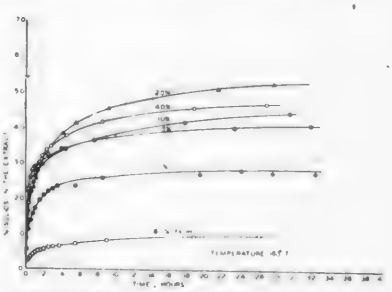

Figure 8.—Extraction of wood of moderate Arabogalactan content with alcoholic solutions.

Table I—PROPERTIES OF ARABOGALACTAN

	Crude	Purified
Color	Tan	White
Water Solubility	Slow to Dissolve	Dissolves Readily
Solutions	Slightly turbid	Clear
Tannins ($FeCl_3$)	Very Marked	Negative
Heat and Acid Produce:	Considerable Charring	Little Charring
Arabinose content	11.58%	11.49%
Infrared Curves	Same	Same

to utilize the procedure of White (6) yielded variable results, although negative tannin tests on the product were obtained. The procedure of Wise, Hamer and Peterson (7) modified slightly by Smith (5) yielded a consistently fine appearing white product with a yield of about 30% based on the original galactan. While the material is improved in appearance, the arabinose content is not increased and the infra-red absorption spectra (Fig. 10) are not altered. The spectrograms of the spray dried crude material, that purified by Smith using the Wise, Hamer and Peterson Procedure and a sample furnished by the Western Pine Association of Portland, Ore. are practically identical. The Western Pine sample was prepared by extracting shredded waste larch with boiling water, precipitating with alcohol and drying over sulfuric acid. The properties of the spray dried material and the purified material are contrasted in Table I. The arabinose content was determined by hydrolysis to furfural and precipitation with thiobarbituric acid.

Solutions can be partially bleached with chlorine or sulfur dioxide, but structural changes and degradation undoubtably result from these procedures. Color bodies in the extract darken on addition of iron salts but do not precipitate with albumin or glue and fail to show other conventional tests for tannins. The use of ion-exchange resins for purifying liquors has not been encouraging. New techniques are needed along these lines if a colorless product is necessary.

By-Product

Insulating board of commercial quality has been prepared from extracted chips. It is believed that board manufacture from extracted chips requires less effort and chemicals than unextracted chips, but this has not been fully studied, although work is in process.

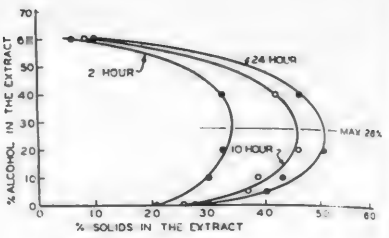

Figure 9.—Effect of alcohol on extraction rate.

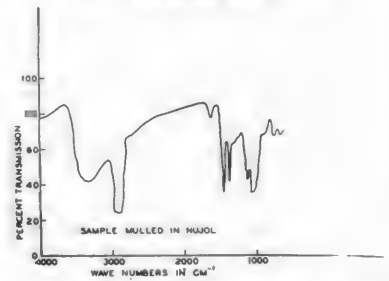

Figure 10.—Infra-red absorption spectrogram of Arabogalactan sample mulled in nujol.

Acknowledgement

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Chemical Utilization and Forest Management[1]

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Forest management plans must be intimately related to the way the crop is to be used. Diversified processes and plants must be developed before intensive forest management is possible or profitable. The relation between chemical utilization and forest management is discussed in some detail.

IN ANY DISCUSSION of chemical utilization of wood, two facts should be kept in mind. One is that a forest will produce a great many products; it will produce sawlogs, veneer bolts, poles, piling, fence posts, pulpwood, and a large amount of material that we now call "logging residue."

The second fact is that utilization practices dictate how the forest will be managed. If a sawmill is the only outlet in the area, the forest will be managed to produce sawlogs; if a pulpmill is the only outlet, the land will be managed for pulpwood.

Here in the Southeast you have seen a one-product farm economy in operation. You know that to have stabilized agriculture farms must produce not one, but a number of products. The same is true in the management of forest lands. To manage timber holdings most profitably we must consider all the products that could be produced on the land and the markets that would bring the highest return (6).[3] We must consider the quality of the wood needed by these markets as well as the quantity. The greatest possible volume of wood from a tract of timber is not always the most desirable, even for pulpwood. Quality and density are very important. Longer rotations with an end crop of sawlogs and veneer bolts and intermediate harvests of other crops appear to be the most

[1]Presented at meeting of the Forest Products Research Society, Florida-Georgia-Alabama Section, Oct. 30, 1953, at Radium Springs, Ga.

[2]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3]Numbers in parentheses refer to literature cited at the end of this report.

effective management plan of the future. From such management ½ to ¾ of the total wood grown would be available for some form of chemical utilization. Diversified utilization processes and plants must be developed before intensive forest management is possible or profitable.

But first, wood utilization in general must be considered. There are two broad types of utilization—mechanical and chemical. Under mechanical utilization would be grouped such products as lumber, veneer and plywood, poles, piling, and fence posts. Under chemical utilization would be the whole range of fiber products, from those made from coarse whole wood fibers to the most highly refined and purified chemical dissolving pulps. Also included would be products made by processes in which the chemical constitution of the wood rather than its size or shape is all important.

Even in the mechanical uses of wood, chemistry plays a large role. Many new products are the result of combining paper, resin, and wood. Low-grade lumber, for example, can be covered with a resin-impregnated paper overlay to mask gaps, checks, and knots and to give a highly paintable product. With specially designed papers the shrinking and swelling of lumber may be partially controlled.

For a long time I have felt that we have devoted too much time to investigating the cutting and uses of high-grade clear veneers. We should spend more time cutting veneer from low-grade logs and finding ways of using the resulting material. One company has done just that and is producing a paper-covered veneer from a hardwood species that is so poor it has no other use (12). Another is using a softwood species—integrating the operation with a plywood plant (13). At least four companies are in production of a product of this type.

Resin Combinations

Paper-covered veneer is proving extremely useful in such varied products as shipping containers and furniture. It seems to have one of the brightest futures of any recently developed product.

Several types of resin-bonded paper honeycomb cores have been designed for use as core material for sandwich panels. In this type of construction most of the stresses are taken by the facings; however, the core may be chosen for its insulating or sound-absorption value. The basic work was completed about 8 years ago. At present three companies are producing a resin-impregnated paper honeycomb core material.

One combination of resin and wood that has reached the proportions of a new industry is laminating in which wood is glued together parallel to its grain. The performance and strength properties of laminated timbers are better than solid ones. Checking and splitting during seasoning may be eliminated. The lower moisture content and the most efficient arrangement of growth characteristics of the wood permits higher strength values. The parts of greatest stress—the face laminations—may be of clear material with center lamina of lower grade knotty material. Not only are timbers laminated but also curved structural members.

The most recent development has been the production of laminated dimension and finish lumber. The latter permits the upgrading of the lower construction grades by trimming out knots and other defects and edge gluing and end scarfing to such products as stepping, siding, and door rails and styles.

Stabilization

A major problem confronting users of wood is the shrinking and swelling of wood under different moisture conditions. At the Laboratory we have worked for many years on the dimensional stabilization of wood and have developed two products that are now in limited use—impreg and compreg (9, 10, 15). Both of these are costly because a phenolic resin is incorporated in the wood structure. With 30 percent resin the shrinking and swelling of wood can be reduced by about 60 percent.

Impreg, the resin-impregnated wood, is being manufactured by one company, not for its dimensional stability but for its resistance to acids. Material for wood tanks to be used for storing acid is being impregnated with a phenolic resin. A small amount of the material has been used in a number of other products.

Two companies are manufacturing the resin-impregnated compressed wood, compreg. Most of it is being used for tooling jigs and forming dies. Its light weight compared to metals, relatively low cost, and ease of repairing make it highly desirable for these uses. One plant reported that its production was increased by as much as four times by the use of compreg dies instead of metal dies. If the resin content is reduced to 5 to 10 percent, the toughness of the product is increased and its resistance to impact or shock is improved. Such material is more suitable for shuttles and picker sticks in the textile industry than the higher resin containing products.

The Forest Products Laboratory is still working on improving the dimensional stability of wood. Much fundamental work remains to be done before a low-cost method will be developed that will have universal application for such highly competitive products as doors, windows and drawers.

Before leaving the subject of improved wood, we should consider the preservative treatment of wood, since that is one way of making an "improved" wood. As the result of more than 10 years of research, Dr. Roy Baechler of the Forest Products Laboratory has developed a new process for preserving wood called the double-diffusion process (1). Although the process was developed primarily for small-scale nonpressure treatment of fence posts, it shows considerable promise for treating lumber. Green posts are placed upright in a barrel containing a copper sulfate solution, and the chemical diffuses into and up the posts. After about 2 days the posts are transferred to a barrel containing sodium chromate solution and permitted to soak for 2 days. The second chemical is taken into the wood structure and the two chemicals combine within the wood structure to form insoluble copper chromate, a compound toxic to insects and fungi. One hundred posts treated by this method have been in a test plot in Mississippi for more than 13 years. To date only one of this group has failed. Other chemicals and many species are under investigation.

Chemical Utilization

Now let us turn to the chemical utilization of wood. The raw material for chemical utilization should be material that has no value for structural purposes, that is, the residues from logging and manufacturing. It has been estimated that over 100 million tons of this material are produced each year in the United States (11).

Residues can be classified as chippable—slabs, edgings, and trim—and nonchippable—shavings and sawdust. Chippable residues can be used for any form of chemical utilization, but the nonchippable residues are the problem children. At present they are suitable only for such low-grade uses as animal bedding, mulching, fuel and a few specialized uses such as floor sweeping compounds and fur cleaning preparations.

At present the most profitable way to use wood residues is to convert them into chips and to process them into pulp. Both softwoods and hardwoods can be used. Each year more barkers (both whole log and slab barkers) and chippers are being used at sawmills and veneer mills to produce pulpable material. In the Pacific Northwest more than 100 chipping plants have

been built at sawmills and plywood plants. The advent of the semichemical process now makes feasible the utilization of the cull hardwoods. Another new process, prehydrolysis kraft, is being used to convert cull hardwoods into high-grade dissolving pulp, the rayon from which is superior for tire cord. However, in spite of the tremendous expansion in the pulp and paper industry, this cannot possibly be the complete answer to the problem of utilizing wood residues.

Recent studies have shown that the residues of most species can be processed into hardboard. Since 1948 the productive capacity for hardboard has doubled and still more plants are being planned (5). Much of this material goes to the industrial market where it is cut up and fabricated into other products. It is made from chips that have been fiberized, formed into mats, and pressed into flat sheets. Resin binders are often used to strengthen the product.

Particle Boards

There is a whole new class of boards called particle boards that are also produced from the chippable portion of wood residues. The wood is usually defiberized in a hammer mill, resin is added, the moisture content is controlled, and the material is pressed into sheets. The Forest Products Laboratory is now evaluating the effect of particle size and shape on the properties of such boards. Core material produced by this method is competing satisfactorily with lumber core in a number of plants. It can be surfaced with paper, specially prepared flakes of wood, veneer, plywood, or even hardboards. Boards made from wood residues are one of the coming industrial materials. I believe we have seen only the beginning of the manufacture of this type of product. One of the most promising products is a board of medium density.

A large unexplored field is the manufacture of a fiber that is suitable for producing molded products with either high or low resin content. These might vary all the way from toy parts and toilet seats to moldings and parts for kitchen cabinets. Experimentally, window frames and sills have been produced. Extrusion molding of shapes shows great promise.

Now let us consider the problem children among wood residues—sawdust and shavings. Wood hydrolysis is the most promising means of chemically utilizing these materials because it is adaptable to all species and all forms of residue (7). This process allows us to separate wood into two major components—cellulose or its products, and lignin.

Theoretically, complete hydrolysis should produce about 1,300 pounds of sugar and 500 pounds of lignin per ton of dry wood. Since some sugar is destroyed by the hydrolyzing chemicals, the theoretical yield is never obtained. However, a percolation process now in use yields about 1,000 pounds of fermentable and nonfermentable sugar per ton of dry wood.

The cellulose fraction of wood contains not only a material that is made up of a building block of glucose (corn sugar), but a material called hemicellulose that contains an appreciable amount of pentose sugars, mainly xylose. Xylose, which will run as high as 30 percent of the cellulose in hardwoods, appears to have a bright future as a raw material for the production of furfural. All of the readily available agricultural residues, such as corncobs, oat hulls, and rice hulls, now are being used to produce furfural, so any increase in production of this chemical must come from a new source. That new source appears to be hardwoods.

Furfural is the final decomposition product of the pentose sugars during the acid hydrolysis of wood. The final decomposition product for the hexose sugars is levulinic acid. Both are valuable intermediate organic chemicals. Levulinic acid now sells for $5.00 a pound and is being used only in the pharmaceutical industry. Its future will be very bright indeed for synthetic fibers if it becomes available in the price range of furfural, that is, 9 cents a pound.

Three companies now have pilot plants in operation for the production of furfural and levulinic acid. The Forest Products Laboratory has been doing fundamental research along these lines for a number of years.

Wood-sugar molasses with a sugar concentration of 45 percent can be used for animal feeding (4). Feeding tests have shown that the sugar in wood molasses is equal to the sugar in blackstrap molasses in feed value.

Wood sugars can be hydrogenated to sorbitol (a commercial humectant), ethylene and propylene glycols, glycerine and erythritol.

A number of different yeasts can be grown on wood sugar. Depending on the type and the growing conditions, they may be high in fats, high in B vitamins, or as much as half protein. One plant now is producing Torula yeast from the sugars in spent sulfite liquor, and another 2½ million dollar plant is under construction. The yeast is used as a high vitamin protein feed and as a source of pharmaceuticals.

The original objective of hydrolyzing wood to sugars was to produce alcohol by fermentation. However, a number of other fermentation products can be obtained under properly controlled conditions. These include acetic, butyric, lactic, and citric acids, and acetone, butanol, butylene glycol, and glycerine.

The use of wood sugar depends upon its production at a cost comparable to the competing sugar whether it is black strap molasses, invert sugar, or corn sugar. Much of the economics of any process of wood hydrolysis is dependent upon a profitable use for the lignin residue or upon a uniform constant supply of sugar at a fixed price.

A number of uses have been found for lignin (3), but much more basic research is needed to establish its exact nature and to put it to best use. It differs from the other constituents of wood in that it is not converted to low-molecular-weight compounds when hydrolyzed with acids. It is a storehouse of aromatic materials whose building block is phenyl propane.

The lignin residue from the sulfite pulping process consists of lignosulfonates that can be converted into vanillin, the vanilla flavoring in your ice cream, and such products as oil-well drilling compounds, tanning materials, and linoleum adhesives. These materials do not use much of the available lignin, but the Sulfite Pulp Mill League of Wisconsin located at the Institute of Paper Chemistry and many other groups and pulp mills are doing utilization research that ultimately will provide a large-scale use for this product. One of the most obvious uses for lignin, since it is the binding material in wood, is as an adhesive or as a component of a plastic. However its flow properties must be improved. Ultimately, because of the great quantities available, the best opportunities for the use of lignin may be in chemical degradation and separation of the various products. Such processes as caustic treatment, pyrolysis, hydrogenolysis, and chlorinolysis or other oxidation processes are possibilities, but much basic research is needed.

From the high lignin residue of the acid hydrolysis process it may be possible to produce an activated char, perhaps by the fluidized bed technique worked out in the petroleum industry. The Georgia Institute of Technology made a valuable contribution to the study of wood carbonization by investigating the fluidized bed principle for producing charcoal from sawdust (14).

While discussing carbonization, we should mention the opportunities in the domestic and recreational market for charcoal produced in small kilns close to the market. Although this use of charcoal appears to be expanding, little has been done in the way of intensive marketing of a specialty

product for the small consumer. It appears feasible that a small cinder block Connecticut type kiln might be integrated with intensive forest management operations to convert logging residues into a cash product, especially in areas where low-cost labor is available. The hardwoods are the preferred species

Extractives, another component of wood, form the basis of the large naval stores industry in this Southeast region. Such an industry can also be integrated into a management plan. The Forest Products Laboratory has done little work in this field in recent years because of the intensity of work carried on by the Bureau of Agriculture and Industrial Chemistry. The Forest Service has concentrated on the forest management phases.

Now I would like to mention three fundamental chemical investigations being carried on at the Madison Laboratory. In the first of these cellulose was treated with high-energy radiation to make a product that is essentially soluble in water (8). This is a drastic and costly treatment. However, a similar but milder treatment may be useful in increasing the reaction speed of cellulose in its conversion to plastics, rayon, and other products. This fundamental research project has produced some interesting and valuable information.

Many of the new developments in wood utilization depend upon gluing pieces of wood together, and yet we know very little about this phenomena. New and better adhesives are developed largely by trial and error methods. The Laboratory now is undertaking, after a lapse of some 20 years, research on the fundamental mechanism of adhesion. The problem is being approached from three directions: (1) the forces of adhesion that bind the adhesive to wood. (2) the forces of cohesion that hold the adhesive together and resist its breaking, and (3) the stress-strain relationships within a glue film. This third part should provide information on the effect of additives on the properties of an adhesive.

The adhesion project is strictly basic research, but we hope the results will be useful in designing and formulating adhesives to do specific jobs. For particle boards and laminated lumber, an extremely low-cost adhesive is needed. In fabricating airplanes, on the other hand, the cost of the adhesive is secondary to its performance.

Tests have already shown that, providing the surface is properly prepared, the cohesive forces are always weaker than the adhesive forces; the glued object does not break at the point of contact between the adhesive and the object, but rather in the glue film or in the material being glued.

Another investigation that will be started shortly is on the fundamental mechanism of natural durability; that is, what is it that makes some woods durable while others decay rapidly? Previous work in this field was not aimed specifically at the fundamental mechanism, but rather at the relation of the molecular configuration including the side groups to toxicity. This work at the Forest Products Laboratory by Bateman and Baechler (2) led to the development of tetrachlorophenol and finally to pentachlorophenol, which now is a recognized preservative.

The reason for looking into natural durability now is the development of new techniques—the techniques of chromatography and infrared spectrophotometry. They should contribute much toward the solution of the problem.

Basic information in the field of chemical utilization of wood is very short. If we are to continue to make progress in this field, we must emphasize basic research right along with the fields of applied research and development.

The development of any chemical process for utilizing wood, or any other material, is expensive. It requires time, money, and manpower. Even with unlimited funds and men it is a rare occasion where a process can be developed and a full-scale industrial plant built in less than 5 to 10 years.

Chemical utilization of wood puts one into the chemical industry where capital costs are high and manpower requirements are low. The capital investment averages about $1.50 for every dollar of manufactured product. For example, if the output of a plant would be valued at a million dollars a year, the capital investment would be about 1-½ million dollars. To develop the chemical utilization of wood satisfactorily, it may be necessary for a number of primary manufacturers in the forest products industries to group themselves together as one major company that will purchase its raw materials from the wood residues of primary manufacturers and forestland managers on a long-term basis.

The Forest Products Industry must not expect the magic wand of research to turn her into a Cinderella. She must do her part by sprucing up and have enough gumption to go to the ball.

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The Oregon Forest Products Laboratory

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Legal status and overall research program are discussed, as well as physical facilities and personnel. Cooperative work to further utilization of Oregon's timber resources is also described in this second article in a series on wood laboratories.

RECOGNIZING THAT the forest industries of Oregon provide the state's greatest source of industrial employment and strongly affect the local economy, the 1941 Oregon Legislature authorized the State Board of Forestry, in cooperation with the School of Forestry at Oregon State College, to institute and carry on research in the fields of utilization, fabrication, and manufacture of forest products in order to further the interests of forestry and forest products industries within the State. Subsequent legislative action authorized the establishment of a forest products laboratory at Oregon State College, such laboratory to be under the direction of the Dean of the School of Forestry. The following article describes the organization and functions of the Laboratory.

Laboratory's Advisory Committee

The law under which the Laboratory operates provides for an Advisory Committee of eight, six of whom are appointed by the Governor. Each of the following agencies or groups recommends a member for appointment: Oregon plywood interests, Pacific Northwest Forest and Range Experiment Station, School of Forestry at Oregon State College, West Coast Lumbermen's Association, Western Pine Association, and the Willamette Valley Lumbermen's Association. The Governor, an ex-officio member of the Advisory Committee, is its chairman, and the State Forester is its secretary.

Functions of the Advisory Committee are:

1. To survey the entire field of research in wood utilization for the purpose of assembling definite information covering current research projects as well as past accomplishments, and rendering practical counsel in the field of economic forest utilization.

2. To explore new fields for the utilization of forest products and to encourage the establishment of new industries of this type within the state.

3. To guide and approve all research activities undertaken by the Forest Products Laboratory.

4. To suggest, as a result of contacts with wood-using industries, promising wood-utilization projects to other research organizations.

5. To recommend the compilation and release to industry and to the general public of all research information and data.

The Advisory Committee is not legally designated a policy-making or administrative group, but because of its intimate contact with the forest products industries and research, its advice and counsel are sought on matters of Laboratory policy and administration.

Financial Support

Financing of the state's forest products research program, which was at first by small direct legislative appropriations ($25,000 in 1941–43), was supplemented in 1947 by the establishment of a "severance" tax on timber. This tax of 5 cents per thousand board feet was placed on all timber in excess of 25,000 board feet as harvested by each operator in the state. The income from the tax was divided, after deducting the cost of collection by the State Tax Commission, 60 per cent for forest products research at the Oregon Forest Products Laboratory and 40 per cent for forest management research by the State Department of Forestry. Income to the Laboratory from this source has averaged over $200,000 per year. Following termination of the 1947 severance tax on June 30, 1953, a new timber harvest tax became effective. This new tax assesses for research 4 cents per thousand board feet on all timber cut (divided as before) and an additional 4 cents per thousand on the timber from certain forest lands in Western Oregon for the establishment of an emergency forest fire fund.

Provision is made for the State Board of Forestry to accept donations for the furtherance of products research. Donations permit accelerated work on a particular project or in one area of investigation by enabling the Laboratory to employ additional technical assistants on a temporary basis.

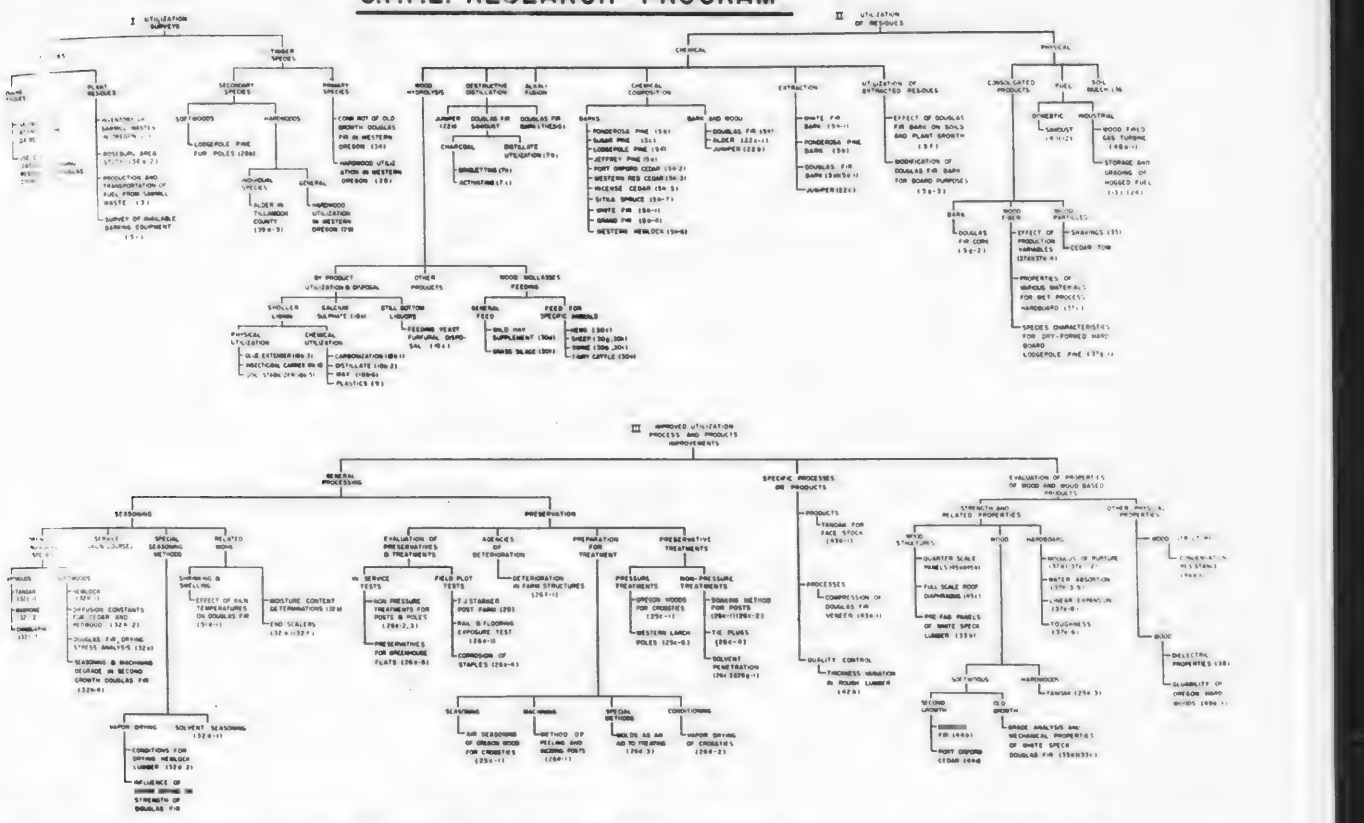
Provision is made also for the Laboratory to receive income from State-owned patents originating at the Laboratory. The State Board of Forestry is authorized to sell, transfer, license or assign any patent rights acquired by the State from any employe of the Laboratory. Income from this source, after deducting an incentive payment to the inventor, is divided 40 per cent to the State's General Fund and 60 per cent to a special account for use by the Laboratory.

Administration of the Program

The State Board of Forestry, cooperating with the School of Forestry at Oregon State College, is deemed responsible for Laboratory policy determination. In this, the Board is aided by the Advisory Committee and by the Forest Protection and Conservation Committee which was established in 1953 to administer research funds and fire funds collected under the new timber harvest tax.

From 1941 to 1953 the Dean of the School of Forestry at Oregon State College was by law the Director of

About the author: Mr. Grantham became Managing Director of the OFPL in January, 1953. He had previously been associated with the Laboratory in various capacities over a number of years while with the School of Forestry, Oregon State College. His first service with the Laboratory was as a research technologist in 1944–45. His experience with Oregon State College included being Associate Professor, Department of Forest Products, in 1946–47, and Professor and Head of the Department in 1948–52. Mr. Grantham's previous experience includes BSF in Forest Products, College of Forestry, U. of Washington, 1934; M. S. in Wood Utilization, New York State College of Forestry, 1935; retail lumber sales in Brooklyn, N. Y. and Seattle, Wash.; Assistant Professor of Forestry, Virginia Polytechnic Institute, 1941–42; and Research Technician, Division of Forest Products Research, Texas Forest Service, 1941–42. He was Chief of the above division during 1944–45.



the Laboratory. He was responsible for over-all management control, but was authorized to employ a Managing Director to handle the internal administration of the Laboratory.

Although a 1953 amendment to the Laboratory's governing laws eliminated the position of Director, the Dean of the School of Forestry still plays a prominent role in the administration of the Laboratory. He is by law a member of the State Board of Forestry, the Laboratory's Advisory Committee, and the Forest Protection and Conservation Committee. Through membership in these policy-making or advisory groups and through the close cooperation of the Laboratory and the School of Forestry, Dean Paul M. Dunn continues to lend the benefit of his experience to the program.

The internal administration of the Laboratory is unchanged, although the Managing Director is now appointed by the State Board of Forestry.

Physical Facilities

The Laboratory is housed in the Industrial Research Building, located at the edge of the Oregon State College campus in Corvallis. This building is a modern, two-story, wood-steel-tile-concrete structure having ground-floor dimensions of 60 by 300 feet. It was provided by the State Board of Higher Education in 1947 in response to statewide interest in industrial research. For the present, the Forest Products Laboratory is sharing the building with the Department of Chemical Engineering of Oregon State College; the Laboratory occupies about one-half of the building. Space is allocated to chemistry and chemical utilization, wood technology, wood seasoning, wood preservation, fiberboard, plywood, timber mechanics, four controlled temperature-humidity rooms and a wood working shop. The building also houses a business office, six staff offices, and a library.

In 1951, a one-story, laminated-arch, frame building was constructed adjacent to the Laboratory, with Laboratory funds, to provide additional space. This structure houses the stockroom, machine shop, experimental gas-turbine project, wood and bark grinding equipment, and two Laboratory vehicles.

The Laboratory already possesses much of the basic equipment essential for wood research and for the duplication of standard wood processing. As the research program expands to cover different fields of wood utilization and processing, essential equipment is purchased, or designed and assembled in the Laboratory shops, to meet the problems presented. Full use is made also of the equipment available at cooperating agencies. Whenever practicable, cooperative research projects are conducted at the industrial plants where they are initiated.

Laboratory Staff

The Laboratory's technical staff of 24 includes chemists, engineers, and wood technologists. Fourteen are employed in the division of physical research, four in the division of chemical research, and three in industry service. The remaining two are the managing director and the technical editor. In addition to the technical staff, the Laboratory employs eight skilled or semi-skilled workers for shop and maintenance duties, or as assistants on research projects; an office or clerical staff of six under a business manager; and from three to six part-time workers, depending upon the number of active projects. An average of four graduate students are engaged in graduate research projects related to the Laboratory program. Most of these have worked in the field of wood or bark chemistry.

Dr. E. F. Kurth, a graduate of the University of Wisconsin, heads the division of chemical research and development. His industrial research experience includes one year with the Du Pont Company and two years as research director of the Gulf States Paper Corporation. He has spent a total of six years in chemical research with the U. S. Forest Products Laboratory and five years with the Institute of Paper Chemistry. His wartime duty with the Headquarters, Army Service Forces, included responsibility for

Oregon Forest Products Laboratory.

standards and specifications on army items of supply and equipment involving lumber, paper and chemicals. From 1943 to 1945 he also served as army representative in the Lumber and Lumber Products Division and Pulp and Paper Division of the War Production Board. He has been chief of the Laboratory's chemical research division and professor of wood chemistry at Oregon State College since 1945.

L. D. Espenas, who heads the division of physical research and development is a graduate of the New York State College of Forestry and University of California. Following industrial experiences in lumber seasoning he served as a technologist at the United States Forest Products Laboratory from 1942 to 1947 with assignments in kiln drying, chemical seasoning and the war-time packaging program. He joined the OFPL staff in 1947 to head the Laboratory's work in seasoning, and has directed the short course in lumber seasoning each year since 1948.

K. B. Bollerslev, in charge of industry service, is a graduate of the College of Forestry, University of Washington, with many years of industrial research and production experience. This includes four years in quality control, research and inspection experience with furniture manufacturers, twelve years as a wood technologist with Rayonier, Inc., and four years in charge of pilot plant operations on fiberboard and adhesives for the Plywood Research Foundation. He joined the Laboratory staff in 1951.

Wood technologists or engineers in charge of the several sections of the division of physical research are younger men but, in total, posses years of industrial, armed service and research experience. Coming as they do from several sections of the country they bring a breadth of ideas and viewpoints to apply to the Laboratory's research program.

Scope of the Research Program

The original 1941 law provided for the initiation of research to improve the utilization of residues arising from the harvesting of forest crops and from the manufacture of lumber and other forest products. It was appropriate, therefore, that first research efforts should be directed toward determining the quantities of sawmill residues available and possible uses for these materials. Since sawdust, slabs, and edgings constitute the bulk of unused wood, the costs of converting these materials into fuel and transporting the fuel by various methods to large consuming centers were studied.

As the needs of the wood industries became more apparent, the scope of Laboratory activities broadened to include work on salvage logging and utilization of logging wastes and secondary species. In turn came projects on the chemical utilization of wastes, the improvement of lumber products through better seasoning and preservation methods, and basic studies on the physical and related properties of wood and component parts of wood products.

Approximately eighty major investigations and fifty minor tests have been completed since the inception of the program. The major investigations are outlined in Figure 1. The unlisted minor tests are principally tests undertaken at the request of individual companies or agencies. Requests for assistance of this type are accepted when:

a. The work will promote improvements in wood utilization.
b. The studies cannot be performed readily elsewhere.
c. The work fits in with the general research program and will contribute additional knowledge in the particular field of investigation.

Major Research Projects

The projects shown in Figure 1 are those which have required several months to several years for completion. A number of these projects are current and a few are described briefly to illustrate major activities of the Laboratory.

Extractives from Douglas-fir Bark: Since the tremendous tonnages of bark brought to Oregon sawmills, plywood plants and pulp mills each year has had little value to the plants, early research efforts of the Laboratory were directed to the chemistry of barks and pioneering studies on the isolation, properties, and potential uses of bark products. Under Dr. Kurth's leadership the Laboratory's division of chemical research made a systematic investigation of the bark of each important timber species in the state.

The basic investigations revealed that Douglas-fir bark not only was available in the greatest volume but contained products offering the greatest commercial promise. As a result, a major research project of the Laboratory has been an intensive investigation of products obtainable from Douglas-fir bark.

Results have shown that three extractives are obtainable in quantities sufficient to offer commercial promise. These are (1) wax, (2) tannin, and (3) a flavanoid substance, dihydroquercetin.

It is anticipated that suitable extraction and refinement of at least one fraction of Douglas-fir wax will provide a high-grade domestic wax comparable to carnauba wax. Major uses would be in polishes and carbon paper. A large eastern firm has undertaken pilot plant investigations of wax production from Douglas-fir bark and may within a year decide to produce such wax commercially by means of the process developed at the Laboratory.

Douglas-fir tannin, available from bark in yields of from 7 to 18 per cent, compares favorably with quebracho tannin for all of the major industrial uses, including use in leather tanning, oil well drilling muds, and concentration of low-grade iron ores. Its commercial production appears feasible, especially if tannin extraction is combined with the recovery of other valuable bark constituents.

Douglas-fir bark provides one of the richest domestic sources of flavanoid substances. Some flavanoids possess characteristics of the so-called vitamin-P and are excellent antioxidants for the prevention of rancidity in fats and oils. Dihydroquercetin, a flavanoid substance found in substantial quantity in Douglas-fir bark (from 4 to 7½ per cent yield), has aroused immense interest since being reported by the Laboratory.

Manufactured Products from Wood Residues: A major research effort of the Laboratory has dealt with fiberboard and particle-board products. Research projects in this field have included:

a. Properties of various species for wet-process hardboard.
b. Properties of various species for dry-formed hardboard.
c. Spray tower application of binders for wood particle-board production.
d. Evaluating procedures for hardboard testing in cooperation with the new hardboard association.

The surplus of wood residue materials developed at sawmills and plywood plants in Oregon creates a tremendous utilization problem. Since

board products offer one of the more promising means of utilizing such materials in volume, this field of research has received major attention.

Early efforts of the Laboratory in this field contributed to the establishment by Ralph Chapman of the first hardboard manufacturing plant in the Pacific Northwest.

Testing of Wood Roof and Wall Diaphragms: In order to provide engineers and architects with more data on the strength of wood in construction, the Laboratory has carried on a wood-structure testing program. Upon the advice of structural engineers the test program has been limited to roof and wall diaphragms. Results of the tests point the way to stronger and more efficiently designed diaphragms, thereby keeping wood in a stronger competitive situation. The West Coast Lumbermen's Association and Associations of Structural Engineers have recommended desired tests; coordinated past, current and projected studies; and made quick use of the results in designing structures.

Vapor-drying Studies: The Taylor–Colquitt Company of Spartanburg, South Carolina, originator of the vapor-drying system of conditioning wood prior to preservative treatment, has been an active cooperator with the Laboratory for several years. The conditioning of western woods by this method was investigated early. More recently, studies on the vapor drying of thick softwood lumber and refractory hardwood species have been initiated.

Western Hardwood Utilization: In the firm belief that Oregon hardwood constituted a valuable, but little used, resource the Laboratory undertook to provide potential producers and users with complete information on these species. This has required such varied research as:

a. Strength and related properties of tanoak.
b. Seasoning of tanoak, madrone, chinquapin and alder.
c. Economic studies of the utilization of alder.
d. Experimental production of tanoak veneer.
e. Application of log and lumber grades to alder and maple and the resulting lumber grade recovery.
f. Collection and dissemination of data on the availability, properties and uses of Oregon hardwoods.

Preservative studies to improve the serviceability of wood and wood products have been extensive but will not be described in detail as they are shown clearly in Figure 1.

Other lines of research, such as the cooperative investigations on wood hydrolysis and the several utilization surveys, are shown in Figure 1. In the interest of brevity these will not be described further.

The primary objective of the program includes the early dissemination of research results through the preparation and distribution of reports. The Laboratory has already prepared more than 100 publications, including technical bulletins, journal articles, information circulars, etc. A recent venture in the publication field is a monthly release of "Laboratory Notes" to better aquaint the State's industries with the activties and facilities of the Laboratory. A list of Laboratory publications is available on request.

Cooperation

The policy of the Advisory Committee and the Laboratory is to cooperate fully with all agencies, both public and private, within or outside Oregon, in order to assemble, develop and make available ideas or techniques that will contribute to fuller utilization of the forest resource. This policy aids in minimizing duplication of work and permits a more efficent use of research funds and personnel.

The advice and information supplied by public agencies (both state and federal), associations, educational institutions, professional societies, private concerns and individuals have been invaluable in shaping the research program. Many have cooperated further by contributing materials, money, man-power or data for current projects.

Cooperation has been extensive with such federal agencies as the United States Forest Products Laboratory, the Pacific Northwest Forest and Range Experiment Station, Bonneville Power Administration and Bureau of Land Management.

Cooperation with such groups as the West Coast Lumbermen's Association, Western Pine Association, Douglas Fir Plywood Association, Hardboard Association, Structural Engineers Associations of Oregon and of California, and American Wood Preserver's Association has proven mutually beneficial.

Cooperation with Oregon State College has been a major factor in the success of the program. Building space and library facilities have been made available to the Laboratory since the initiation of the program. In addition, several divisions of the College, notably the Schools of Agriculture, Engineering, Forestry and Science, plus the Agricultural and Engineering Experiment Stations have cooperated in

Typical equipment at Laboratory.

specific projects. The Laboratory's location on the campus has also encouraged graduate student research in forest products to the benefit of both the Laboratory and the College. The Forestry Research Foundation has financed several graduate Fellowships for study on Laboratory projects.

The State Forestry Department has shared responsibility with the Laboratory for several projects that were concerned with both the management and utilization of timber, and has contributed helpful advice or assistance in many instances.

Private cooperators have been so numerous that any attempt to list them might result in failure to mention a valued contribution. The willingness of private concerns to furnish advice, data, materials and money has been an important factor in the success of the program. Their assistance not only has assured a lower cost and an earlier completion of work, but has provided the benefit of broader experience in planning research and in applying results.

Advisory Services

As a corollary of the research program the Laboratory has been called upon to provide extensive advice to individuals and industries on all matters pertaining to the production and utilization of wood and wood base products. These advisory services take the form of answering written requests for information, conferring with visitors who bring their problems to the Laboratory, and "trouble shooting" visits to industrial plants to determine the causes of difficulties, and make recommendations for their correction.

These services are those that commercial laboratories or consulting engineers would find too varied or too limited in scope to be of interest, for they are primarily advisory in nature. In total, the services makes a heavy demand on staff time but are justified in order that greater returns may be obtained from Oregon's timber resource.

Some Non-Destructive Tests For Wood[1]

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Reviews non-destructive methods of testing wood now in use and potential methods as yet not accepted by industry. Improvements or developments needed to gain acceptance of these latter tests are outlined.

Introduction

DURING THE PAST DECADE considerable interest has focused on non-destructive testing methods applicable to wood since the methods are unique in that the samples remain undamaged and therefore from the standpoint of quality control a total inspection can be carried out. As for research use the methods allow repeated measurements under various test conditions on individual samples and thereby permit the collection of highly quantitative data. Markwardt (16) has noted that rapid practical non-destructive tests remain one of the important unsolved problems for the strength evaluation of wood. This is natural where the existing methods have been generally destructive. Similar unsolved problems prevail in other fields of enginering materials. This paper is a survey of non-destructive tests now in use and those that may have eventual application to wood.

Hanstock (9) in his survey of tests for metals has given us an excellent background for outlining a series of comparable tests for wood. Yet, due to the porosity and non-metallic nature of wood a number of these tests do not apply. On the other hand, wood has certain features that do permit inspection procedures not possible with the metals.

As the term denotes, non-destructive testing is the evaluation of materials without damage. There are a number of tests that do alter in a minute way the properties of a sample; however, these are listed here as non-destructive since they can be readily used for lumber without changing the quality of the end products.

Given a sample of wood, a number of major properties can be listed, such as mechanical, electrical, acoustical, chemical, thermal, etc. Where such properties can be evaluated non-destructively, we may have a technique for measuring quality. In the case of most materials, the first characteristic that strikes the mind is appearance and the evaluation of various phases of this has been the first non-destructive test developed for wood.

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, November 5-6, 1953, at New Haven, Conn.

Visual Inspection

It may seem facetious to introduce this particular method in the survey; yet, it illustrates in brief what a non-destructive test is. The grading rules for logs and lumber have been the main standards for the industry. In wood products manufacture visual inspection proceeds along a part or all of the production line. The inspection of kiln loads by the skilled operator, the determination of type and degree of decay by the pathologist, the nature of insect infestation by the entomologist and the recognition of abnormal wood are a few other examples. Visual inspection has its limitation and with the more refined use of wood other tests have become necessary.

Radiography

The application of X-rays to a study of solid materials is well-known. As the X-rays usually emanate from a point source, considerable analysis is required to interpret the absorption patterns for the inspection process. A number of such studies have been carried out for wood. The first investigation of X-rays as an inspection tool for poles was conducted by Zucker (25). He found that X-rays provided a better inspection procedure than the boring test in determining the proportion of sound and unsound wood. A west coast mill has successfully located metal objects, stones and pitch pockets to a depth of 18 inches by a portable fluoroscope. Gregory (8) has reported that termite cavities can be distinguished from decay pockets. Likewise, the presence of insects in timbers can be detected by X-rays as mentioned by the English (7). Due to the nature of the divergent rays through the three dimensional object and the necessity of interpretation of the pattern in depth, X-rays have limited use in the detection of minute features. Nevertheless for certain uses, they play an important role.

Recently fluoroscopic inspection where the viewing is presented by a screen rather than by photographic plates has become important as a quality control device with the improvements in design resulting from new developments. Although it cannot be expected to replace radiography as a final inspection procedure, it has advantages in that many views of the same sample can be taken and that no plates are required. The reduced cost in operation makes fluoroscopy an important supplementary tool in radiography.

Magnetic Metal Detector

The presence of nails or spikes in saw and veneer logs may often reduce the production output, and the early detection and removal of metal objects are highly desirable. Numerous devices, some based on surplus mine-detectors, have been adapted or specifically designed for the location of ferrous metals in wood.

Walters (24) describes two types of mine detectors where the limit of detection of ferrous metals is about five inches. The maximum distance of detection depends on the size of the metal fragment. A German reference reports on an instrument which will detect small iron objects at a distance of 5.5 cm. and 2 cm. fragment at 20–30 cm. Thus, the maximum range is from five inches to a foot. The magnetic detectors offer another non-destructive approach to the location of metal in timber.

Surface Roughness

Occasionally it is necessary to check the surface roughness of wood either to determine the effectiveness of woodworking machinery or the smoothness of finished surfaces. Profile measuring equipment designed for testing metal surfaces appears in some instances to be satisfactory for tracking the roughness of planed surfaces and for indicating differences in wood structure. The commercial instruments operate through a sensitive stylus actuating a microinch recorder through suitable circuits. However, it is apparent that a single traverse is not sufficient to give a statistical picture. A replica technique has also been employed to obtain a picture of an area. Selbo (21) has shown that incident lighting can be used to detect sunken joints cer-

tainly a type of surface roughness. Technologists have employed a similar method for evaluating smoothness of finishes. Lutz (15) has described a technique for measuring roughness of veneer by a straight-line shadow-sectioning method.

Surface Stresses

The presentation of surface stresses falls in the category of non-destructive testing provided the stresses involved are well below the elastic limits of the sample investigated. Dial and optical gauges have been the old stand-bys. In recent years two new developments have provided additional tools, especially in the field of materials testing. The first is the use of brittle lacquers and the second the electrical wire strain gauges. Certain features of both make these useful tools in the analysis of wood products and especially in wood structures (6).

Color Tests

These tests usually depend on the color reaction of woods to certain chemicals. For example, the red and white oaks are easily and rapidly separated on the basis of a benzidine-sodium nitrate solution application, a practical test for the selection of oak ship timbers. This and a number of other methods for distinguishing specific woods are given by Stearns and Hartley (22).

Slope of Grain and Hardness

As the strength, warping and machining characteristics of wood are influenced partly by slope of grain, the rapid measurement of this gives an index of the quality of lumber or veneer in its end use. The well-known scribe procedure has been established by F.P.L. along with other methods for detecting slope of grain (1).

Heiden (12) describes a portable hardness tester by which the compression strength of wood is measured inversely to the depth of punch depression. Both the scribe and hardness tester damage the wood surface and therefore are limited to the raw material. Nevertheless, these are classed as non-destructive as the surface area involved is usually small and can be removed in the manufacturing processes.

Radioactivity

The technological effect of atomic energy has been enormous and with the commercial availability of a number of radioactive substances the avenues for wood research have broadened. Since the war radioactive tracer methods have been found to be useful tools for studying the passage of preservatives into wood. Studies have been carried out at the Bell Telephone Laboratories (2) on the concentration and distribution of radioactive strontium in sections of poles. Peter (18) has carried out similar investigations with radioactive mercury.

Radioisotopes can also be applied to the measurement of density or thickness of wood products as the absorption of the radiation is a function primarily of these two factors. Sandermann (20) mentions a paper measuring device based on the absorption of beta radiations. A comparable instrument has been incorporated into the paper thickness control in mills in this country. Exploratory work at the College of Forestry, State University of New York, has shown that suitable beta emitters may have promise for density measurements. However, for the particular emitter available only the very low density boards could be tested up to 4/4 thickness, the range being approximately 1/4 for the heavier woods to 4/4 for the lighter. On the other hand, gamma radiation has been found to be too highly penetrating for lumber. It may be that softly penetrating gammas will prove satisfactory for timbers and even lumber. The initial strength of radiation, the wavelength distribution and half-life period are some considerations in the selection of suitable emitters for wood.

Electrical Moisture Meters

Electrical moisture meters are excellent examples of instruments whose operations are non-destructive. Among a number of electrical properties, direct current resistivity and the dielecsensitive to changes in wood moissensitive to chanages in wood moisture and less so to the other wood variables. Two distinct types of moisture meters have been developed based on these electrical properties. The needle-electrode and the contact-electrode types are widely used in the industry. In addition to spot testing for moisture, the electrical moisture meters have been modified for continuous moisture detection as reported by Hefferline (11) and Partch (17).

As the moisture content changes during the progress of decay in wood along with other factors, Richards (19) has suggested the possible use of an electrical test for decay based on extensive experimental work. The detection of incipient and early decay by non-destructive means is of considerable importance to wood users. At present decay is detected by impact or toughness tests usually destructive.

Vibration Tests

Some of the measurements in vibration for investigating the mechanical properties of wood are resonance, pulse and continuous wave transmission, and internal friction or damping. The frequency range may be from subsonic to ultrasonic.

The resonance techniques are familiar ones and have been adopted for the vibration testing of standard beams (3). A similar technique has been developed for testing plywood plates or panels (10). The tests give the resonant frequencies which in turn are related to the elastic or stiffness properties of the samples. Since the stresses due to the vibration are low, these are non-destructive.

Firestone set up a practical defect-detecting instrument for metals using pulsed utrasonic energy of high frequencies (4). A modification employing lower frequencies served in the dynamic testing of concrete and wood by Leslie (14). Work at the College of Forestry at Syracuse with equipment of like design has shown that shock pulses can be transmitted through eight feet of wood along the grain. The sound velocities through irregularly shaped specimens of wood can be easily determined by the pulse technique where it would be practically impossible by resonance methods. As sound energy is gradually dissipated in its travel through wood, the rate of energy loss or attenuation serves as an index of the quality of material in the sound path provided there is no reflection of energy off the side walls of the sample. For example, voids in sandwich material can be located from the attenuation profile obtained from continuous ultrasonic transmission (5).

The internal friction or damping of wood is another property of wood obtainable from the vibration tests. The sensitivity of the damping capacity to treatment has been of special interest to the investigators in metals and alloys (23). Although much basic data have been accumulated on the internal friction of different kinds of wood by the various vibration techniques as compiled by Hearmon (10) and Kollmann (13), little information is available on the influence of wood variables on internal friction and the possible applications to non-destructive testing. Thus, one of the objectives of studies on internal friction would be to obtain empirical relationships between this and the conventional mechanical tests.

Summary

The non-destructive tests listed here represent some of those in use and of the potential methods yet to be accepted by industry. The future development of non-destructive testing procedures will hinge largely on the matching through research of the physical

properties of wood and those techniques which are most sensitive in their response to changes in these properties. There will undoubtedly be no single test suitable for wood evaluation. As in the case of the present comprehensive mechanical testing of wood, a number of non-destructive methods must be tied in to give an over-all measure of quality. The prediction of how a particular wood product will react under service conditions will be strengthened by the use of non-destructive methods.

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Keeping Laboratory Records for Patent Purposes[1]

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Describes in detail the methods for keeping daily records as work on an invention progresses. Necessity for preparing records in such a way that they are obviously authentic is stressed.

IT IS AN UNFORTUNATE FACT that many technically trained people are reluctant to keep careful laboratory records of their research and development work. It is highly important, however, that such records be kept. Laboratory records summarize the work done and hence are available to refresh the memory of the worker in the future, as well as to serve as a guide for further research to be conducted by himself or by others. Also, such records serve the important function of protecting inventions, and it is the primary purpose of this discussion to consider the manner in which this result is afforded, as well as to indicate the proper manner of keeping laboratory records so that they will furnish competent evidence of their content.

Laboratory records protect inventions by assisting in the preparation of the patent application covering an invention. Such an application must contain a complete description of the invention, its mode of operation, and its advantages over the prior art. The logical and best place to go for this information is to the laboratory records.

After the patent application has been filed, laboratory records are useful in providing information which may be employed in overcoming references cited by the Patent Office. Thus, during the prosecution of the application a technical article may be published, or a patent issued that discloses but does not claim the subject matter of the invention. When such a reference is cited by the examiner, it may be overcome if the inventor can make a proper showing of completion of his invention prior to the effective date of the reference. The laboratory records then may be consulted for the necessary information and to prove his point the inventor's response to the

[1] Presented at meeting of Pacific Northwest Section, F.P.R.S. held in Bremerton, Wash. on October 13, 1953.

citation desirability may include photostatic copies of pages of his records.

Also during the period of its prosecution the inventor's application may be placed in interference with the conflicting application of another for the purpose of deciding who is the first inventor. In these proceedings it may be necessary to establish the date of conception of the invention, running dates showing diligence in perfecting it, and the date of reducing it to practice. Even after the patent issues, it sometimes is necesary during litigation to prove the fact that the invention was made at an early date in order to confirm the validity of the patent. Properly kept laboratory records obviously will supply the needed information for these purposes.

It is to be noted particularly that the contingencies referred to above may, and often do, arise many years after the laboratory work has been completed. This makes it of primary importance that adequate records be kept.

Avoid Fraud

One guiding precept to be kept constantly in mind when keeping laboratory records is that such records, like wills, must be maintained in a form which will avoid the possibility of fraud. Accordingly, the records should be kept in bound notebooks having serially numbered pages. Separate notebooks, possibly supplemented by a diary, may be used for each separate project.

If desired, each notebook may be interleaved with perforated sheets which provide removable carbon copies. The bound original then may be filed and the extracted sheets used for reference.

It is preferable to use ink or indelible pencil when making entries. Avoid making erasures. If an error is made, strike it out, leaving the stricken portion legible so that it may be explained later.

Write legibly. Avoid the use of code numbers unless a key is available. Date each entry and keep the entries strictly in date order. Line out all blank spaces. Keep the notebook current. See that the inventor's name and affiliation are prominently placed on it. Be sure that each entry is properly authenticated and witnessed. File the notebook in a safe place and do not discard it after a period of a few years. As has been emphasized above, notebooks often are of particular interest many years after the work has been done.

The second guiding precept to be kept in mind relative to laboratory records is to make them complete and understandable. All of the work done should be recorded and summarized in such a manner as to be understandable to an outsider. It preferably should be organized and written so that a trial judge, or other person who may not be technically trained, may gain an understanding of the invention by reading it.

Accordingly, it is desirable that the records be organized in somewhat the same manner that engineering, chemistry or physics laboratory records are kept by students in academic courses in these subjects. Preface the entry with a general statement of the purpose or object to be accomplished. Mention the disadvantages of the prior art procedures which it is sought to overcome. Record in detail the equipment and materials employed, the proportions of any ingredients, the procedure followed, and the test data or results obtained. Note particularly any irregularity or unexpected result.

Keep in mind that patent cases have been won or lost because the inventor noted or failed to note in his notebook such simple circumstances as that a reaction mixture was cooled by the introduction of ice into the mixture. Refer to or incorporate supporting materials, such as correspondence, graphs, photographs, blue prints, shop records, flow plans, and invoices for equipment and materials. All of these items help complete the record, establishing the fact of conceiving an invention and of working diligently to reduce it to practice.

After an experiment has been completed, state the conclusions reached. Use positive terms. Show satisfaction with the experimental results. Avoid making negative and derogatory statements concerning them. Keep in mind that in order to demonstrate the fact of having made an invention the test results need only confirm the theory of the invention and show that it is feasible and operable. It need not be perfected to its final stage, since it is recognized that improvements in equipment and operating procedure may result from future work.

A third guiding precept to be kept in mind when preparing laboratory records is that the records must be duly authenticated and corroborated. This is perhaps the most important requirement of all, since, if not present, the entire record may prove to be ineffective as proof of inventorship. It is absolutely necessary that the fact of making an invention be established through the testimony of a corroborating witness.

Witness Each Page

Hence it is important that not only should each page of the notebook be signed and dated by the inventor, but also that each page should be signed and dated by a corroborating witness. The form used for witnessing is variable, but a simple entry such as

Witnessed and understood
October 13, 1953
John Jones

is sufficient. This preferably is placed on the lower portion of the sheet. The date to be set forth is the date of witnessing, not the date of doing the experimental work. It therefore follows that the witnessing should follow promptly the date of making the record.

It also is highly important that the witness be someone who understands what he is witnessing. Accordingly, the signature of a secretary, clerk, notary, or other person who is technically untrained and cannot understand the disclosure, or of a technically trained person to whom the invention has not been explained, is ineffective. The witness preferably should be someone who has seen or is familiar with the environment in which the work is being carried out, i. e. the laboratory, shop or plant. In general, the witness should know enough about the invention which he is witnessing so that the information would not be lost if the inventor should become unavailable.

A logical person to secure as a witness is a co-worker or supervisor who has followed the work done by the inventor and therefore is familiar with it. It should be kept in mind however that if the co-worker or supervisor is a joint inventor, he is not a proper witness. Still further, it should be remembered that by witnessing an invention, the witness disqualifies himself from thereafter claiming that he is the inventor of the subject matter which he has witnessed.

Prove by Tests

After the preliminary work has been done and duly recorded in the laboratory notebook, there comes a time when laboratory or plant tests prove the validity of the inventor's theory and the feasibility of the proposed invention. In other words, the invention has been reduced to practice. Witnessing and corroboration of the reduction to practice is of particular importance. It is essential that the witness thoroughly understand the invention. If the invention is mechanical, he must study the machine, witness its operation, and understand the manner in which it operates.

If it is an electrical invention, the witness must trace and understand the circuit and know what it accomplishes. If the invention is a composition of matter, the witness must know what the constituents are, the proportions

employed, and the function of each or, in any event, the net result of combining them. If the invention is a chemical process, the witness must know the identity of the reagents employed, their relative proportions, the procedural steps used, and all the operating conditions. If chemical reagents are employed, the witness must know of his own knowledge that the reagents are those claimed. In other words, he cannot take the statement of the inventor that a given reagent bottle contains a stipulated chemical substance.

Thus it will be seen that with respect to corroboration of the reduction to practice of the invention, it is desirable to have the invention repeated by the corroborating witness, particularly if the invention is a chemical invention, using reagents which he can identify positively. The test should be made, if possible, under service conditions, keeping in mind that these may be even simpler and less rigorous than certain laboratory testing procedures. The corroborating witness then is in a position to assert that the invention actually has been reduced to practice.

From the foregoing, it is apparent that keeping laboratory records which meet the strict legal requirements demanded of records of this class may be a tedious and time consuming procedure. If for one reason or another they are not kept in this manner, it is suggested that when the inventor has reduced his invention to practice, he prepare at that time a supplementary memorandum or work summary which conforms strictly to all of the requirements.

Thus it should be prefaced with a statement of objectives, followed by a complete description of the invention, including sketches, a list of materials employed and their proportions, a description of operating procedures, etc. This should be followed by conclusions affirming the successful reduction to practice of the invention, perhaps reaffirming the manner in which it overcomes the prior art difficulties. This disclosure should be dated and signed by the inventor and witnessed by one or more persons who understand the invention and who, of their own knowledge, can attest to the accuracy of all of the items disclosed in the memorandum.

As of the date of preparing this memorandum, the inventor then will have a properly authenticated document establishing the fact of his having made the invention. This may be somewhat later than the date which he might have established if his laboratory records were kept properly. However, it may antedate by a considerable period the filing date of his patent application and therefore be useful to him later on.

Thus, in conclusion, from a patent standpoint, laboratory records are useful in preparing patent applications, in overcoming references cited by the examiner during prosecution of the application, and in proving priority of invention both in interference proceedings during the pendency of the application and in litigation subsequent to the issuance of the patent. Complete and current records should be kept in a form which avoids the possibility of fraud. Supplementary and supporting records of all kinds should be referred to and incorporated whenever possible. The conclusions reached should be set forth in positive terms, clearly establishing the fact that the invention has been completed.

All records should be carefully authenticated, and reduction to practice of the invention should be corroborated by someone who understands the invention, who has witnessed its execution, and preferably by someone who has carried it out independently. The corroborating witness should be as disinterested as possible, and necessarily must not be a joint inventor. The resulting records then will be in a form which are acceptable as proof and which may be instrumental in assuring that the inventor will be able to secure a valid patent on his invention.

What's New At the Forest Products Laboratory in the Field of Wood, Paper, Resin Combinations?[1]

At the meeting of the Midwest Section of the Forest Products Research Society in Madison last July, representatives of the U. S. Forest Products Laboratory discussed some potential new products in the field of wood, paper, resin combinations. What follows is a report of that discussion.

Herbert Fleischer, FPL (Moderator): The first speaker on the panel discussion will be Robert J. Seidl of our Pulp and Paper Division. Mr. Seidl will discuss the papers, the impregnating resins, and the treating processes used to make overlay sheets.

Robert Seidl, FPL: The subject of composite products of wood and paper probably deserves a good deal more organized attention than our laboratories and industries have been able to give it. As we study ways of improving the service of wood products and of extending the supply of wood, we find more and more uses where paper can be used to advantage in combination with wood. Because we at the Forest Products Laboratory work so extensively with lumber, plywood, and housing panels of all kinds, as well as pulp and paper, we are always on the lookout for ways to combine these products.

We might begin today by asking the question, what does paper have to recommend it for use with wood? Wood and paper have much in common as we all well know; to make paper we take the well-aligned fibers as they exist in wood, jumble them all up, then spread them out into a flexible sheet material that has high strength and uniformity. The fiber is the building block, and the variety of properties that we can achieve with it is great indeed. We can vary density, strength, thickness, absorbency, porosity, brittleness, toughness, color, and a number of other properties at will. Like wood, paper has a predominant grain direction, but it is not nearly as highly grained as wood.

Because of the excellent dispersion of fibers in the plane of the sheet, paper resists checking upon weathering and provides a uniform base for painting. Although paper has always been a good material when kept dry, it has had the bad characteristics of losing practically all of its strength when wet. When certain resins were developed some years ago, however, this difficulty was overcome. Papers can now be very stiff and strong even when wet. They lose some strength, but not much more than wood loses when it is wet. As a result, paper

[1] Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, Madison 5, Wis., Maintained in cooperation with the University of Wisconsin.

wet or dry, can have physical properties very close to those of wood itself. As a point for conservationists, paper can be made from low-grade wood, and it can supplement products from saw logs and peeler logs.

You can see that I take an optimistic view of the prospects of combinations of wood, paper, and resin. The advantages outlined are clear enough, but the economic factors and the specific products that can use these advantages are not nearly so clear.

Most of our generalizations this afternoon will apply to the less costly overlays that are made of unbleached wood pulps and have a low resin content. These overlays are considered for the surface treatment of wood, plywood, or veneer, or for cross-banding sheets in plywood. There is also, of course, the large, well-established business involving the costly melamine and phenolic plastics that are used on a wood base for tables and counter tops.

Our studies on papers have been concerned with the effects of types of fiber, resins, methods of resin addition, and cure of the resin, and the way these variables affect strength, water absorption, abrasion resistance, water vapor transmission, and dimensional stability. We have developed standard ways to evaluate the ability of the papers to mask defects in veneer and the dimensional restraint that paper can apply to veneer. For example, we have studied the swelling and shrinking of treated papers in the machine and cross mechine directions and the swelling and shrinking of overlaid veneer, and have done a good deal of theorizing on the limitations of bonding a material like paper that moves in both directions to a material like wood that moves principally in one direction when it gets wet. Out of this we developed curves showing the stabilizing effects of paper on veneer as well as on the strength and stiffness of overlaid veneer. We also developed a way of computing the strength and stiffness of an overlaid veneer from the engineering properties of the component parts.

Methods of adding resin to paper were also studied. One way of doing this, of course, is to make the paper and then impregnate it. Another is to impregnate the paper on the paper machine as it is being made. Still a third is to blend the resin with the fiber in the beater and from the sheet in the presence of the resin. Each one has advantages and problems. We are often asked which one is best. There can be no simple answer to that question; there probably is no "best" method because so many factors must be considered.

Information on overlay papers is much more understandable when it is related to products and use requirements; we can discuss the paper itself more a little later after we have heard more about uses and products.

Fleischer: Thank you, Bob. Mr. Seidl reminds us a little of the man in the newspaper cartoon who was standing very proudly next to a tree that he had made by chopping down a tree, grinding it up into pulp, giving it various chemical treatments, then sticking it all together again. That's about what we are trying to do here. Now I'd like to have our next panel member tell you a little about the combination material that is built up using the paper or resin-treated paper Bob Seidl was talking about. Bruce Heebink of our Division of Wood Preservation will discuss overlaid veneer, overlaid plywood, and overlaid lumber products.

Bruce Heebink, FPL: Bob has given you some idea of the variables involved when we put resin and paper together. If I were to add to that the multiplying factors of the base and its variables of species, moisture content, and types—such as veneer, plywood, and lumber—I would need more time than I've been allotted, so I am going to pass over that phase very rapidly.

Although there have been sporadic attempts to do research on combinations of paper and veneer or plywood over many years, the work really started in earnest at the Forest Products Laboratory early in the last war with the development of resin-impregnated paper materials. The name "papreg" was coined for these materials. We combined papreg with various types of veneers and made satisfactory products that had exceedingly high strength. Since then we have broadened our research to include masking, decorative, and structural overlays. We have investigated such properties as vapor transmission, warping tendencies, abrasion, masking ability, and durability of most all of these papers on veneer and on plywood. We have made overlaid veneer and overlaid plywood on the scale of durability all the way from something that is good only for interior use, such as drawer bottoms or cabinet backs, to something that is entirely boilproof, can be used for cement forms and boat applications, and can be left out in the weather.

Paper-overlaid products are now rather familiar, and you can buy them in one form or another at almost any lumberyard. They are available, but that's not saying that all of the problems have been licked. There are still problems of selecting exactly the right overlay material for the application and problems of applying it on the base. We also have the problem of finding new uses; these, we feel; will pretty much take care of themselves as suitable face veneer becomes more scarce.

Now, the theme of the discussion this afternoon is what's new at the Forest Products Laboratory in the field of wood, paper, resin combinations. Overlaid veneer and plywood, although they still may be new to the layman, are no longer new materials to you in the wood industry and to us at the Forest Products Laboratory. What about an overlay on lumber? Would we like to hide in a piece of lumber such things as large, juicy knots, sound knots, or pitch-pockets? Are the stresses involved so high that paper won't stand them? How about the economics? Is the price difference between a clear board and a No. 2 or 3 common board great enough so that we can apply an overlay to the poorer material and pay for the labor of putting it on and for the material? These are some of the questions we have asked. We have some of the answers, but not all of them.

Looking back we find that many years ago someone at the Laboratory thought of combining paper and lumber, and some work was done on it. However, because of the limitations on resins and adhesives available at that time, the early researchers were considerably handicapped. The idea then was that a very thin overlay, almost of the tissue type, would be used to improve the surface for paintability on certain problem species. Since that time a number of products have come to our attention that must have one good surface, but the base and sometimes the back may be defective. Two common examples are siding for the exterior of a house and panels that might go into the base or partitions of kitchen cabinets.

The problem in both of these applications is primarily one of masking, with painting a strong secondary consideration. We'd like to mask, for those applications, rather large pitchy knots, and pitchpockets. Our work on overlaid veneer and plywood has led us to believe that the best masking sheet is a rather thick sheet impregnated with resin and fully cured before it is applied to the base. On a veneer or plywood base the masking sheet is applied in a hot-press; that isn't likely to work with lumber liberally sprinkled with pitchy knots and pitchpockets. Nevertheless, our first attempt here

was to use a commercial masking sheet having a high temperature phenolic glue on one side. We applied it to a low-quality board in a hot press at 275° F. The expected happened; over all of the pitchy knots we had bleed through, blisters, and poor bond. This was also true when we reduced the press temperature to 230° F.

Next we attempted to use one of the new acid-catalyzed phenolic resins that cure at room temperature in a conventional cold press. We found that a No. 2 common white pine board liberally sprinkled with knots could be covered with a commercial overlay about 18 thousandths of an inch thick so that those knots couldn't be seen.

The next step was to take a number of boards about 12 inches wide and 8 feet long, of typical No. 2 common white pine, cover them with an overlay, and put them out on our test fence on the University Farm. These panels were assembled about 8 feet square with a north and a south exposure. Along with them we put out some similar knotty pine material without the overlay and a panel of high-grade redwood siding. Each panel was painted with two typical white house paints on the north and the south sides. They were exposed in September 1952, and after 9 months the overlaid material was in excellent condition. There seemed to be no warping. We saw no evidence of the knots, although we had photographed each piece so we could locate them. The pine without the overlay showed all of the knots. The redwood, as you might expect, was in good shape.

A few pieces of similar overlaid material were exposed on the outer wall of our veneer mill where we might expect moisture to work through the wall during the winter. We wanted to see if we would get excessive warping or blistering. They have been on since last fall, and they are in excellent condition. There seems to be no warping, and the paint looks about like new.

In another case we used a white overlay that might be suitable for the base or partitions in kitchen cabinets. With this overlay we are able to use a number 2 or 3 common instead of higher quality material. This white overlay, incidentally, may not require painting. It is a nice clean, white-looking product that should sell rather easily.

These are only two of the many potential applications of an overlay on low-quality lumber. Others might be such things as house sheathing and crating, where material of a lower quality could be used, and possibly interior wall panelings, where we would want a high-quality overlay and defect-free, paintable surface. Each overlaid product must be designed carefully so that it will meet the requirements of the use for which it was intended. I doubt if there will ever be an all-purpose masking sheet that could be used on any base and always provide an acceptable surface. The overlay combination of resin and paper and the method of applying it to the base all must be chosen carefully if the best product is to result.

Fleischer: We have now been introduced to the subject of papers, resins, overlaid veneer, overlaid plywood, and overlaid lumber. Perhaps more questions have been raised than answered. However, that is up to you to decide. The floor is yours to ask questions, to make comments, and to give us the results of your experience.

Henry Crandall—Mosinee Paper Mills Company: Do the properties of paper, such as strength, make much difference in the final product or does it act primarily as a career for the resins?

Seidl: The paper is anything but a carrier for the resin. The paper is the overlay and the resin supplements its properties and overcomes its loss of strength when it gets wet. The resin adds more than wet strength, but in no sense is the paper just a carrier for the resin.

With plywood I don't think the strength of the overlay matters very much, but the abrasion resistance, paintability, and density of the sheet, and its absorbency to paint or paint solvents would make quite a difference. If you're making an overlaid veneer, the strength will be very important, and by the right combination you can design a paper with certain engineering and elastic properties after resin treatment and cure. This paper can be combined with a veneer and a prediction made of the properties that will result in both principal directions of the overlaid product. Because strength is important, it is obvious that the grain direction of the paper should be at right angles to the grain direction of the veneer. You can then consider the whole thing a sandwich panel if you wish. In its design you can put just enough paper or paper strength on both sides so that you will get a product that is equally stiff in two directions.

Ralph Casselman, Paine Lumber Company: You said that you use the acid-cured resins cold. Are they also equally suitable when they are used warm or hot, or does the heat itself cause trouble?

Heebink: They would be equally suitable used hot if we could use them that way on the board, but the trouble is that the pitch boils out of the knots even at a temperature about as low as you can run a steam press. At 220° F. we had about as much bleed through as we had at a higher temperature. So the only glue we have found satisfactory so far is a room-temperature-setting phenol.

Casselman: Would resorcinol resins also be satisfactory?

Heebink: I think so. It is a matter of the cost and the quality that you want. As for durability, the resorcinol resins certainly ought to be adequate.

Fleischer: You mentioned, Bruce, that some of these panels could be used for interior cabinet work. You wouldn't insist on a phenol resin there, would you?

Heebink: No. Interior types of adhesives would be satisfactory there.

Paul Smith, Consolidated Water Power and Paper Company: Has this work on overlays on lumber been restricted to softwoods?

Heebink: Our work has been primarily on softwoods. We have done a little on hardwoods, but don't have much to talk about. Stresses are different, of course.

S. F. Stevens, Eggers Plywood and Veneer Company: Have you ever been able to successfully mask fir plywood with a sheet of paper?

Heebink: Yes. In some cases it masked very well. I think the overlay that masked best, though, was about 32 thousandths of an inch thick. What kind of paper was that, Bob?

Seidl: It was a rather unusual pulp. It was made of steam-cooked spruce chips that were milled and made into a very thick sheet. It was not a very strong paper, but it did a good job of masking plywood where strength was not important.

Fleischer: I think Mr. Stevens is particularly interested in furniture applications. The type of material we have worked with so far has not been in that class where you would put on, say, a high-gloss finish. Right?

Heebink: That's right. Primarily, we have been masking for paint application. The overlay covers loud grain, boat patches, cookie patches, and splits up to about ⅛ of an inch. To cover larger splits you would need an exceedingly thick overlay.

Seidl: Paper does not provide the type of masking you need with a

decorative plastic table top, if that is what you are interested in.

Casselman: Could we get an estimate of the cost per square foot of this 18 thousandths sheet that you described and arrive at some rough estimate of cost?

Seidl: I don't think I can give you an estimate. There are a lot of things that enter into the cost of a thick, specialized, resin-treated sheet. We don't think it will remain costly if it is made in large enough quantity.

Armin Elmendorf, Elmendorf Research, Inc.: I have been figuring costs lately and it appears the sheet costs anywhere from 1.3 to 1.9 cents per square foot with the usual 30 percent resin concentration.

Casselman: For two sides that would be $40 a thousand plus the cost of application, which would probably be another $40. We would have on the order of $60 to $80 a thousand added to the original lumber cost. With $80 lumber we might arrive at something on the order of $150 to $160. This is just a rough guess.

Elmendorf: I think the industry figures about 5 cents a square foot for 2 sides, including the cost of bonding.

Crandall: How much does an overlay reduce the swelling of lumber?

Heebink: We don't know too much about that, but we were surprised—Bob and I—that the paper didn't break right away. We took samples of overlaid lumber a half inch wide and soaked them, completely soaked the pine board, and there was no rupture of the paper.

Seidl: You might all think about that a little. It is rather astounding that paper like this could be bonded to a thick piece of lumber, thrown into water, and not be broken. The lumber moves a good deal more than the paper can stretch, as we understand the stretch of paper, and yet the paper doesn't break.

Elmendorf: Your paper must have an expansion or stretchability of 4 percent.

Seidl: Right, and as we usually measure it by paper tests, it doesn't stretch that much.

Elmendorf: In other words, you are compressing the wood to some extent.

R. I. Hiller, American Cyanamid Company: Bruce, what is the resin used in these treatments and what percent resin do you use?

Heebink: The overlaid material that is out on the test fence has about 18 percent of a beater-addition type phenolic resin.

Fleischer: Bob, would you explain what is meant by beater-addition type resins?

Seidl: Briefly, these special resins are put into the mixture of fiber and water, then made to precipitate on the fiber. Paper is made out of the blend. This results in a sheet directly from the paper machine that has the strength, stiffness, and wet-strength needed for this purpose. That is distinguished from the process of making a paper first and then soaking it in resin.

H. B. Puff, Durey Plastics and Chemicals, Inc.: What retention do you get with these beater additions?

Seidl: I frankly don't know the retention we get. We don't have much more luck measuring it than most people do. We do know what we add and what effectiveness we get out of it, however, and that is significant. Certainly we lose some resin in the water, but we don't know how much.

Puff: Do you feel that is more effective than the usual impregnating treatment?

Seidl: It just depends on what you are making and what equipment you have. If you have a stream pollution problem maybe you wouldn't dare consider the beater-addition method. If you have a size press on a machine, you may like the size press treatment with water-soluble resin. If you have a machine that makes paper of the exact width or exact multiple for the product, this may be the controlling factor. There is no simple answer to that question.

Elmendorf: Have you observed any tendency on the part of the paper to crack or slip due to the expansion of the wood? There must be some point at which that takes place—at some thickness or resin concentration.

Heebink: I don't believe we have made enough tests to answer that, Mr. Elmendorf. I have the feeling that the combination of thickness and resin concentration we have here is just about at the borderline. This is about 18 thousandths of an inch and 18 or 20 percent resin.

Seidl: We do see breaks in the paper occasionally, and that is no surprise at all to me. What continually surprises me is how often it does not break. It is really remarkable. You just pointed out that the paper would have to stretch 4 percent to go along with the wood. Well, it doesn't seem to stretch that far, and yet it doesn't break.

Heebink: About the only indication of surface checking that I have seen is on one of our siding pieces that did not go out to exposure but remained in the Laboratory. We inspected it carefully and found a check about half an inch long. When we scraped off the overlay to see what was under there we found a great big knot with a split in the middle of it.

L. Spiwak, Snyder Chemical Corporation: Checking of the overlay would depend not only on the thickness of the overlay but on the density. A lower density overlay would be less likely to check. The manner of resin treatment of the sheet would also affect the tendency to check. Treatment of the sheet by saturation generally gives a more complete dispersion of the resin over the fibers and at the crossing points of the fibers, which tends to give a more rigid system and one that would rupture more easily. A beater-additive type of treatment gives less rigidity, and permits some slipping of the cellulose fibers. For that reason I beileve you would get better results for exterior exposure with an overlay made with a beater-additive type of treatment.

Seidl: I agree with your generalizations, Larry, but when you consider density you must think of the range you are in. If you are in a high-density plastic range, you may have trouble with checking if the overlay is too thin. As you reduce the density, you get something closer to wood itself and it seems to go along with the wood so there is less checking. If you go down too low in density just to avoid checking, you may have a punky sort of sheet that will crack with slight swelling of the wood. We made some very soft sheets originally—so soft that they weren't of much interest for overlays. They would soak up too much paint and rub off when they were wet. In spite of all the variations we have made, I am wary of any generalizations on exactly what you do to avoid checking, at least as far as resins contribute to check resistance.

Spiwak: Have you done anything on treating the pulp with a combination of a beater-additive thermosetting resin and a rubber or elastomeric latex?

Donald Fahey, FPL: Yes, we have made sheets of that type. The sheets we made were mainly to improve the impact resistance of the paper; we have never used any of the latex-resin combination papers as overlays on plywood or veneer.

Seidl: The first thing you think of when you are fighting checking, of course, is if the paper overlay could be made to stretch more it

ought to check less. But we have papers that stretch much farther than they ought to without checking, so it is a very complicated thing and we haven't quite been able to pin it down. However, I think the addition of a relatively small amount of latex would be beneficial.

Fleischer: So far we have barely scratched the surface in these combination materials by talking about papers, resins, and overlays. Another large field is that of making little particles out of the wood and then binding them together to make a panel material. Dr. Locke, chief of our Division of Derived Products, is going to introduce this subject.

Ed Locke, FPL: Before I go into the subject as Herb introduced it, I want to mention two combinations of wood and resin developed at the Laboratory. I am sure you are familiar with compreg and impreg; both are suitable for many specialty uses. One manufacturer is now making a resin-impregnated wood tank for acid resistance and, using another resin, for caustic resistance. I think that is a definite step in the right direction.

Now I'd like to go on to my main subject—boards. Boards are probably the most live topic in the field of chemical utilization, except, perhaps, pulp and paper. Pulp and paper plants, of course, require 10 to 20 times as large a capital investment as board plants. In the board field we could discuss products varying in density all the way from mats that will barely hold their shape to very dense and strong die stock. We could discuss boards that are formed essentially of wood fibers or fiber bundles from water slurries and those that are air-felted and dry-formed. I want to pass over all of these and discuss particle boards, particularly the work we have started in this Laboratory on particle boards.

Particle boards lend themselves to the utilization of residues from sawmills, planing mills, and other wood processing plants. We are concerned here with utilization—using waste to produce a product that will have a definite place in the forest products industry. We want to make a product that will take the place of or supplement high-grade wood, or perhaps I should say solid wood. For some uses it might compete with plywood; again it might compete with yellow-poplar lumber for core stock. There are a number of places where it fits into the picture. It has also developed some uses of its own. No one has really tried to merchandise this material because it has all been taken as soon as manufactured.

The work on board that we are doing here is a project of three divisions. First is the work in Pulp and Paper on the wet-formed process that is related to pulp and paper techniques. Second is a combination of the work in Timber Mechanics on the strength and the testing of sample boards, and the work we are doing in Derived Products. We are not trying to develop a process, and I want to make that clear. Everybody and his brother has a process, and we do not propose to develop one. We might have ideas on processes later, but at present we are merely trying to study a number of variables that come into the making of particle boards.

The first variable that we felt should be investigated was the size and shape of particles. I can't tell you much about the results of that study because the boards we have made are in the Timber Mechanics humidity rooms undergoing cyclic humidity changes and are being tested for springback, dimensional stability, and bending strength. We hope to have that work completed and published within 6 months.

We have made cubes, flakes, curls, and strands with painstaking care. We have picked those as being representative types of particles. We have not studied the effect of the various resins. We have studied somewhat the effect of varying amounts of one resin using 4 percent resin, 8 percent resin, and I believe a few boards with 2 percent resin. We have studied the effect of pressure, and the effect of the various types of particles. We have used two commercial products — green planer shavings from the West Coast and a coarse grade of excelsior from Wisconsin. We used these to get an idea as to what was possible from the run-of-the mill byproduct of a sawmill or another industry.

The coarse material seems to lend itself to core stock pretty well. The ultimate goal in the hardboard industry, I believe, is a product with the strength of plywood—both in actual strength and in dimensional stability.

There are a good many variables that we could study. Some of those would be the effect of the resin and the effect of using various types of overlays. We have been able to triple the bending strength by using a high-grade flake particle for the faces. It doesn't take much high-grade material, but enough to give a coverage. Even in the core, as you would expect from studies using pulp and paper techniques, the undamaged fibers give the strongest boards.

The moisture content of the material is important while you are making the special flakes or curls or particles and during the pressing cycle. For instance, we had considerable trouble with moisture with a board made entirely of flakes. Those flakes matted down so close together that there was no place for the moisture to escape. As a result we had blisters.

Fleischer: Do I understand from what you have said, Ed, that you are getting strengths that are comparable to those in plywood or lumber?

Locke: No, Herb, I didn't mean to infer that we were getting strengths comparable to lumber or plywood. The ultimate objective is to reach the properties of plywood, but I doubt if we do.

Casselman: Isn't there a trend toward use of more urea resin in construction of such boards, and if so, is it justified?

Locke: I wouldn't say there is a trend. There is a desire to keep the costs as low as possible and for interior exposure urea is entirely satisfactory. The problem you get into with urea is the same as that with a moisture-resistant plywood the first thing you know people put it outside and it comes apart. When a particle board comes apart, you have nothing left but sawdust or particles.

Casselman: We get samples of imported boards about every week and most of those seem to be bonded with urea resin for the sake of color.

Locke: The Europeans and the Scandinavians, if I may separate them from the Europeans, are very much prone to use urea resins. They haven't developed the use of phenolics like we have in this country. Personally, I prefer phenolics because they are of the exterior type. On the other hand, a number of products now on the market are made from urea and seem to be giving satisfactory service. It seems to me if you bond the face veneers to the core stock with urea resin, it is entirely adequate to use the urea resin for the core. On the other hand, I would feel safer if I had a phenolic-bonded core.

Fleischer: Is there any panel being made that might be called an exterior type?

Wayne Lewis, FPL: Two midwestern companies are using phenolic resins. If the board is being manufactured exclusively for use in another manufacturing operation, like the core stock for furniture in the same company, urea could be con-

sidered entirely adequate. A problem develops, however, when it is sold in the retail market. Once it leaves the manufacturer, you have no assurance on how it is going to be used and, if it is used in exterior application, it may disintegrate or delaminate.

Steffey, **Curtis Millwork:** The board we make is for exterior uses, such as panels on garage doors, so it must be the phenolic type.

Puff: Perhaps one of the biggest fields is in molded parts as opposed to flat boards. Toilet seat manufacturers have almost exclusively gone over to a wood waste toilet seat; in most instances they use phenolic resins. Croquet balls have also been made very successfully; as a matter of fact, they have stood up much better than the maple croquet balls that were formerly used. There is quite a bit of work being done on duck pins and duck pin bowling balls and in many places molded articles have proven to be much more satisfactory than solid wood articles. I think the general picture has improved considerably in the last year. There is quite a bit of phenolic being used.

Locke: The products you mentioned are largely made of fine particles rather than the coarse particles that we are discussing and require considerably more resin than the 4 percent we are thinking about.

Puff: Board manufacturers probably apply 6 percent to get flexural strengths of around 4,000 pounds per square inch. With molded materials, such as toilet seats, croquet balls, and the like, they probably use in the neighborhood of 20 to 25 percent resin.

Elmendorf: I was in Europe last year to visit as many operations as I could in this field. One of the first operations I visited was just this side of the Iron Curtain in Germany. The aim was to make a flooring to take the place of wood floors that had been destroyed by bombing, so they got some government money for it. They built a very substantial plant in which the fibers or the raw materials used were cut with a special saw—kind of a rip-saw operation—that cut strands parallel to the grain of the wood. These strands averaged half or three-quarters of an inch long. When I visited that plant they were expecting to change over because that particular kind of fiber was no longer the ideal fiber for that purpose. They had been producing around 30 tons of such board a day and, incidentally, they found that the real market for that kind of board is not for floors but for cores in furniture panels.

After seeing the German plants and their problems I am inclined to believe that we are paying a little bit too much attention to strength—unnecessary amounts of attention to strength—and not enough to texture. It's not so easy to produce a board having a density of 0.55 to 0.60 and at the same time get the uniformity of structure that you must have in order to prevent the shavings or particles from telegraphing through the facings. The shaving, particle, or strand will telegraph through the veneer in due time when there have been sufficient number of changes in moisture content of the board. In this country we haven't succeeded in making any board that is satisfactory for the furniture trade largely because we haven't covered the ground they have abroad. We don't have the experience as yet. Besides, the furniture industry in this country is reluctant to make a change. It can still get lumber, whereas abroad they can't, so they are forced to use particle board. We should pay more attention than we generally do to the structure of the board and to its density because they are both tied up with manufacturing problems and are very difficult.

Locke: I agree, Armin, that the variables that go into the making of these boards are not understood. We feel that our contribution in this field is a study of what happens under certain conditions with certain materials rather than a process. Some manufacturers have had a lot of trouble with the material under certain conditions; for instance, this problem of springback—dimensional stability in the plane of pressing—is a very sore spot in some boards.

Elmendorf: I think it is important that something be done about developing common terminology. There are too many words used in this field now; I think we should begin to pin down our ideas so that we are talking about the same subject. Although technically it might be used for everything—for shavings, fibers, and chips—I prefer to use the word particle for the particular small object that results from the breaking action of the hammer mill. There is a tendency over here to refer to all of these boards as chipboards. Well, they are not chipboards in the sense in which the paper mill uses the word chip. So we should reach some common terminology on these things—chips, shavings, particles, fibers, strands.

Locke: I agree.

Fleischer: Now let's turn to the next topic—the uses of these paper-overlaid panels. Ed Clarke of our Materiel Containers Division will discuss their uses in containers and packaging.

Ed Clarke, FPL: Packaging is one area in which paper-overlaid veneers have been adapted for use, and one in which we probably can expect a more widespread use. The Laboratory has been testing the suitability of paper-overlaid veneers as panel materials in conventional cleated-panel boxes as well as in the containers of special design. If these materials find greater use in the container field, it will, of course, be a step in the direction of more complete wood utilization.

The importance of packaging in the United States is indicated by the fact that about 20 percent of our total lumber production and 25 percent of our total paper production is now being used for containers. The crux of the packaging engineer's problem is to design a container of the lowest possible cost that will protect the contents from damage until it reaches its destination. It is not enough to design a container of balanced construction, for such a container might be underdesigned and not protect the item, or it might be overdesigned and not be the most economical. We must, therefore, consider the basic requirements of an ideal container when we look at these paper-overlaid veneers as a container material.

There apparently are several ways in which these materials can be used in container work. One of them is as panel material for the cleated-panel box. We also have two containers exhibited here that are of special design and have certain patentable features. We have not tested these containers, but a box similar to one of them has been found to be a suitable alternate for a conventional box for a weight of contents of 100 pounds. We have also tested various paper-overlaid veneers when used as panel material in containers and compared them with the performance of standard panel materials. In most instances we found them satisfactory. Naturally there are weight-of-content limits as well as size limits. It will take further investigation, however, to find out just what those limits are.

One of the great advantages of these materials in the container field is reduction of tare weight. This is important for most mediums of transportation, particularly air cargo. Although we are not too familiar with costs, they might be cheaper

than some of the materials for which they are a suitable alternate.

At present we have a study underway in which we hope to gather enough information to draft a military procurement specification for this type of material. There are three manufacturers, each making more than one thickness of paper-overlaid materials. In addition there are such variables as species of core stock, kind and thickness of paper overlays, and kind of adhesive. A specification based on material requirements to satisfy all these variables would be extremely cumbersome, so we hope to be able to base it on performance.

H. N. Calderwood, Consultant: Can you use paper-overlay containers for handling truck garden produce, such as celery and lettuce? There are two factors to consider—one is that the produce is often packed wet or packed with ice, and the other is the possibility that the bonding resin will impart a taste to the food.

Clarke: We have not investigated whether or not the resin would impart odor or taste. We do know, however, that there have been some satisfactory trial shipments of apples and other fruit with containers made of these materials.

Calderwood: Could you, by means of these paper overlays, use a lower quality veneer than is normally used and make hampers suitable for shipment.

Clarke: I would think so, but we haven't checked that.

Fleischer: We have had, of course, considerable experience in the use of glued products in various applications including food containers, and I'm sure that as far as the durability of the glue joint is concerned, we could make some predictions. I believe we could also predict whether or not it would impart an odor or taste to the food. Could I ask Don Brouse for a comment on that?

Don Brouse, FPL: I do not think we have enough information on glues and their effect on foods to make very positive statements. I would guess that the more durable glues under wet conditions of packaging would have an undesirable effect on certain foods that pick up odors readily, like butter. I am not at all sure about fruits and vegetables.

Hiller: During the war we used urea resins to the extent of about 5 percent with starch in bonding corrugated and solid fiberboards, but even 5 percent was not permitted if they were to be used for packing foods. We packed canned goods in these cartons for overseas shipment, and in some instances there was actually enough free formaldehyde to rust the cans. I think that experience indicates that if you use urea resins you are asking for trouble.

Puff: The can companies have done a terrific amount of work on phenolic gluing. In some food packages they do use modified phenolics that are much better as far as toxicity or imparting odor or taste is concerned. But generally speaking, I think you will find that phenolics, such as those used in impregnating paper, are bad as regards contamination of food. Some of the completely thermosetting resorcinol resins or the acid-catalyzed phenolic glues may not be too bad, but there again, it would depend completely on the food. Butter is very susceptible; one company making particle boards for use in a kitchen unit received many complaints because butter was being contaminated by the phenolic glue used in making the board.

Fleischer: Packaging, of course, is just one outlet for these combination materials. To discuss their uses in housing, I am going to call on Otto Heyer of our Division of Timber Mechanics.

Otto Heyer, FPL: Our job in housing research at the Forest Products Laboratory requires not only that we be familiar with practical day-to-day problems, but that we stand back and try to view developments in the house building business with perspective and a detached point of view. By analyzing the trends and relating them to future needs and markets we can begin to make some predictions. This kind of speculation is of value to manufacturers and home builders because it stimulates thinking about better ways to build houses.

This afternoon you have heard a number of speakers describe some of the work we are doing on wood, paper, resin combinations. As these speakers pointed out, these combinations can be used in many ways in house construction. Theoretically, at least, houses could be made entirely of paper and waste wood products.

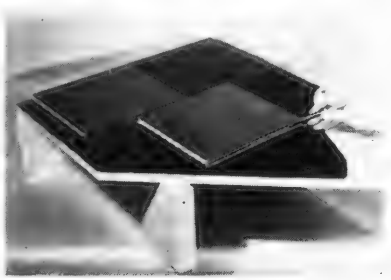


Figure 1.—Plywood floor tiles covered with a paper-plastic (papreg) sheet about 0.09 inches thick. Tests have shown that these tiles maintain a smooth, lustrous finish free from scratches and scuff marks. A floor of this material has been installed in the lobby of the U.S. Forest Products Laboratory.

Many of you have seen the papreg floor in the lobby of the Laboratory. It is the largest paper-plastic and plywood floor in the world. This model (fig. 1) will give you some idea how those floor tiles were made. The top skin or plastic surface was made by molding about 39 sheets of high resin-content (about 35 percent) paper under high pressure. This plastic sheet was about 0.09 inches thick, and it was bonded to 5-ply Douglas-fir plywood in a second operation. In that same operation a thinner plastic balancing sheet was bonded to the underside of the panel to insure high dimensional stability. The tiles are 10½ inches square, fitted with tongue-and-groove joints. They were laid on a cement slab and bonded with a mastic. Before the lobby floor was laid in March 1953, we made a 7-year study of an experimental office floor laid at the Laboratory in 1945. This office floor has maintained a smooth, lustrous surface free from scratches and scuff marks.

The new floor is expected to require very little maintenance. Nothing more than conventional cleaning should be necessary to preserve the natural luster. As a matter of fact, the tiles seem to be self-polishing. Unlike a varnish floor, the finish will not wear off.

While considerable research has been done on this type of flooring, it is still in the experimental stage and is not made commercially.

Another idea we plan to put to practical test soon is a ventilated type of house siding (fig. 2). The weather face is of Douglas-fir veneer covered with a masking overlay of paper. It has a honeycomb backing made of a kraft paper treated with a synthetic resin for moisture resistance. The honeycomb is bonded to the facing with a phenolic resin and heat cured. This siding will be applied over sheathing and building paper just like conventional siding.

Because the ventilated siding will permit water vapor to escape from within house walls, it should eliminate the problem of paints blistering due to condensation of moisture within the wall. The honeycomb may also give somewhat better insulation than solid wood. Note that in this construction veneer with a paper overlay takes the place of high-quality lumber.

Figure 2.—Ventilated siding made by covering veneer with a masking overlay of paper and bonding it to a honeycomb backing of kraft paper treated with synthetic resin. Because this siding will permit water vapor to escape from within house walls, it should eliminate painting problems caused by condensation within walls.

While this ventilated siding has run part of the gamut of research, we plan now to use it on an addition to one of our buildings to test it in service.

Paper, resin, and veneer have also been blended into a ceiling tile or wall panel that is uniquely decorative and has sound-absorption properties similar to those of perforated acoustic tile (fig. 3).

The new acoustical material is made of thin facings of Douglas-fir white-pocket veneer glued to a 1-inch thick paper honeycomb treated with resins to strengthen and waterproof it.

The new acoustic ceiling has already been installed in one office at the Laboratory as a practical test of its sound-deadening effect and its decorative qualities.

Several people have asked me about the sandwich panel test unit built on the Laboratory grounds in 1948 (fig. 4). The test unit was built to study the effect of long-time exposure on sandwich construction under simulated house conditions.

The unit is made of several types of sandwich walls, floors, partitions, and roof panels. The exterior wall panels all have honeycomb cores but were faced with veneer, plywood, or aluminum facings for comparative purposes.

The 4- by 8-foot panels used in prefabricated houses have a certain amount of bowing. However, tests made on this experimental unit show that this bowing is not detrimental to the strength or maintenance of the unit. Larger panels may give different results, but at present we have no data on the subject. Except for these few observations, the unit is entirely too young at present to give us many answers.

Fleischer: Thank you, Otto, for telling us some of the ways these combination materials can be used in houses. I would like to ask Don Laughnan of our Wood Preservation Division to tell us whether or not we are going to have trouble painting these paper-overlaid panels.

Don Laughnan, FPL: We have found that overlays with resin contents below 20 percent are too absorbent for the conventional types of house paint primers on the market. Bob Seidl assures me that we can eliminate that problem by calendering the paper. Although the lower resin content papers are more difficult to paint and give us trouble with the first coat, we find that we can get uniform coatings with the second or third coats.

Tom O'Neil, Masonite Corporation: Have you put up actual walls with that ventilated siding?

Heyer: No, we have not as yet put up any test panels. However, that is in our program for this year.

R. W. Whitaker, A. O. Smith Corp.: Do you get any transfer of moisture through your paper honeycomb core, not along the corrugations or flutes but rather through it?

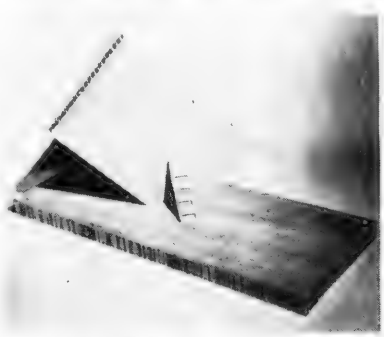


Figure 3.—Ceiling panels of white-pocket Douglas-fir veneer over a honeycomb core of resin-treated paper. These panels have unique beauty and sound-absorption properties similar to those of perforated acoustic tile.

Figure 4.—A cross section of part of the sandwich panel test unit built on the Laboratory grounds in 1948. The test unit was built to study the effect of long-time exposure on sandwich construction.

Seidl: Yes, the honeycomb is quite permeable in all directions. We make no attempt to keep the water from moving one way or another. As a matter of fact, we use an unsized paper that is quite absorbent to water, but it retains its integrity in the presence of that moisture.

Fleischer: We have covered only two of the major uses of some of these combination panel materials. There are, of course, many others. At present, quantities of overlaid plywood are being used for concrete forms, for example. According to reports, it has a real advantage for that purpose because the panels can be easily stripped off and cleaned, they resist rain and snow, and they may be used up to 100 times. Other outlets for material of this kind are in luggage, and in railroad car and bus construction. Walk-in lockers and coolers are being built with overlaid plywood quite extensively. The military agencies are using quantities of it for floats, barges, walks of various kinds, platforms, and so on. So there are many uses that we haven't touched upon at all here. But I hope we have given you at least a general picture of what's new at the Forest Products Laboratory in the field of wood, paper, and resin combinations.

Shrinkage and the Development of Defects in Veneer Drying[1]

HERBERT O. FLEISCHER

Technologist, Forest Products Laboratory[2] U. S. Department of Agriculture, Forest Service

In a previous article (3)[3] the author presented a summary of results of a study of drying rates of veneer. This second paper presents additional information about the effects of various drying temperatures and other factors that affect drying rates on shrinkage and the development of defects.

Development of Drying Stresses

THE DEVELOPMENT OF SOME TYPES of drying defects is associated with stresses that arise in the wood because of differential shrinkage through the thickness of the piece, or along the length of the piece, at some stage during the drying cycle. Examples of this phenomenon in lumber are end splits, casehardening, and honeycombing. Can such stresses develop during the drying of wood sections as thin as veneer, much of which may be 1/8 inch thick or thinner?

In the previous article on drying rates of veneer, evidence was presented to show that diffusion of moisture was not the sole controlling factor in most veneer drying; and that a moisture content gradient was usually not observable through the thickness of thin veneer during that part of the drying cycle when the average moisture content dropped below the fiber saturation point (between 25 and 30 percent moisture content).

The conclusions as to the presence or absence of a moisture gradient were based on temperature data discussed in the previous article. These data are illustrated in figure 1, which is repeated from that article. In the 1/4-inch specimens, the existence of a temperature gradient from surface to interior throughout the drying cycle was taken as evidence of the presence of a moisture gradient, and rates were found to be comparable to those of lumber. In 1/8-inch specimens dried at 250° and 350° F., a temperature and moisture gradient did not exist after the average moisture content had dropped below approximately 30 percent, and the temperature of the drying specimen had risen above approximately 212° F., the boiling point of water.

Shrinkage of wood occurs only when the moisture content drops below the fiber saturation point. Moisture above this level may evaporate just as water evaporates from a free water surface, without affecting the dimensions of the wood fibers. Only when the wood fibers begin to give up "bound water" from between the fibrils that make up their cell walls do the dimensions of the cells begin to decrease. When the cells making up the surface layers of a piece of wood drop to a moisture content below the critical point, while the cells making up the inner bulk of the piece do not, internal stresses develop. Drying stresses resulting from unequal shrinkage can be reduced by reducing the magnitude of the moisture gradient during that part of the drying period, when some or all of the fibers have begun to shrink.

Test Methods

The tests that provided the data on shrinkage are the same as the drying rate tests described in the previous paper (3).

Shrinkage measurements were made on 144 specimens of yellow-poplar heartwood, 3 by 6 inches in size when green, and 1/32, 1/16, 1/8, or 1/4 inch thick. The specimens came from two different logs that varied greatly in initial moisture content and to a lesser extent in density and other characteristics. The width of the specimens was measured green to the nearest 0.01 inch. Then the specimens were experimentally dried to a moisture content of 1 to 2 percent above the equilibrium condition and finally brought to the ovendry condition. The width of the ovendry pieces was measured. Experimental drying conditions included all combinations of temperature, varying in three levels (150°, 250°, and 350° F.), air velocity, in three levels (200, 600, and 1,000 feet per minute), and absolute humidity in two levels (very low and very high). The "low humidity" atmosphere had an absolute humidity of 0.029 pound of water per pound of dry air. The "high humidity" air contained 2.9 pounds of water per pound of dry air, except when the temperature was 150°, when it contained 0.144 pound of water. The specimens were dried primarily to determine drying rates.

The results of the shrinkage measurements indicated that there was a significant variation in shrinkage that appeared to be related to the development of drying stresses. For this reason, further tests were made to examine residual stresses and defects present in the veneer dried under various conditions.

Heartwood specimens of yellow-poplar and sweetgum, closely matched with specimens that had been used for the drying-rate tests described in the previous paper in this series, were dried as before. Specimens were 3 by 6 inches in size and 1/8 or 1/4 inch thick. Drying temperatures were 150°, 250°, and 350° F. The air velocity parallel to the surface of the veneer was 600 feet per minute. Only the low humidity condition was represented, with an absolute humidity of 0.029 pound of water per pound of dry air.

The specimens were dried in the special drying apparatus built for the drying-rate tests. They were then conditioned to a constant weight in a controlled humidity room at 30 percent relative humidity and 80° F. Strips 1/2 inch long in a dimension parallel to the grain were then sawed from the middle of each specimen. These were set on edge and split through the middle with a knife. The

[1] This report is a sequel to the paper "Veneer Drying Rates and Factors Affecting Them," by the same author, that appeared in the previous issue of the Forest Products Research Society Journal. It is based on work done at the Forest Products Laboratory and submitted to the Graduate School of Yale University as a dissertation for the degree of Doctor of Philosophy. The detailed report under the title "Drying Rates of Thin Sections of Wood at High Temperature" has been published as Bulletin No. 59, Yale University, School of Forestry, New Haven, Conn.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to articles cited at the end of this paper.

Table 1.--Tangential shrinkage of individual yellow-poplar specimens under various drying conditions

Drying conditions			Tangential shrinkage[1]							
Absolute humidity	Temperature	Air velocity	Specimens from log 1				Specimens from log 2			
			1/32 inch thick	1/16 inch thick	1/8 inch thick	1/4 inch thick	1/32 inch thick	1/16 inch thick	1/8 inch thick	1/4 inch thick
	°F.	Ft./min.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Low	150	200	6.64	7.31	6.64	8.97	6.62	7.64	7.67	6.33
"	150	600	7.64	6.31	5.98	7.64	7.64	7.00	7.67	6.98
"	150	1,000	6.00	5.98	6.98	6.98	7.33	7.64	7.62	6.33
Low	250	200	7.64	7.31	6.64	7.64	6.31	5.65	7.00	6.31
"	250	600	7.64	5.98	5.65	4.32	7.64	5.65	6.98	5.33
"	250	1,000	6.31	6.31	5.00	5.65	6.00	6.33	6.64	5.00
Low	350	200	6.31	7.31	6.31	5.65	6.31	7.00	6.00	5.98
"	350	600	6.31	5.65	4.65	3.65	6.31	5.98	5.98	5.65
"	350	1,000	7.31	4.65	5.65	4.65	6.64	6.33	6.67	5.33
High	150	200	6.64	5.67	8.31	4.67	6.29	7.33	8.33	7.33
"	150	600	7.31	5.33	6.98	6.67	6.67	7.95	8.33	7.33
"	150	1,000	5.32	6.00	7.00	7.67	5.67	6.31	8.33	6.67
"	250	200	6.31	6.31	7.14	5.15	7.67	6.67	7.67	6.62
"	250	600	8.31	6.98	4.98	4.32	6.67	6.67	7.67	6.00
"	250	1,000	5.98	4.98	5.32	5.65	7.28	6.62	7.33	5.67
"	350	200	6.31	5.32	4.33	4.32	8.64	5.67	6.67	6.00
"	350	600	6.64	5.65	4.32	3.32	6.00	6.00	6.67	5.63
"	350	1,000	6.98	5.32	3.99	3.65	8.00	6.00	6.67	5.00

[1] Shrinkage in percent is based on green width. Dry dimensions were taken after the specimens were oven-dried.

amount of bowing that occurred in the two halves was a measure of the residual stress in the wood. Portions of these specimens were also examined under the microscope.

Results and Discussion

Widthwise or tangential shrinkage of all yellow-poplar specimens used in the drying-rate tests, when drying to the ovendry condition, is given in table 1. The results of tests for residual stress in the dry pieces of yellow-poplar and sweetgum are illustrated in figures 2 and 3. Honeycombing that occurred in sweetgum specimens is illustrated in figure 4.

Shrinkage: Shrinkage data shown in table 1 indicate a considerable variation in shrinkage, apparently varying with changes in thickness and drying conditions. Data include those obtained on the 1/4-inch specimens, which, as mentioned previously, belonged in a class with lumber as far as drying phenomena are concerned, whereas the thinner specimens dried in a different manner.

An analysis of variance (1) was made of the data, and it was shown that the effects on shrinkage of temperature, thickness, and differences between the two logs were highly significant. The effect of air velocity was significant only at the 5-percent level. Atmospheric humidity had no significant effect on shrinkage, but the interaction between logs and humidity had a highly significant effect. Table 2 illustrates the effects of the various significant factors by giving shrinkage values averaged in different ways. It shows, for example, that the tangential shrinkage was less at a high drying temperature than at low temperatures, and that it was less at a high air velocity than at a low air velocity. In general, external conditions that tended to increase the rate of drying resulted in a reduction in shrinkage during drying, except that shrinkage was less in thick veneer than in thin water.

The significant difference in shrinkage between the two logs represented in table 1 may be related to differences in the density of the wood, as wood from the log that had the highest specific gravity shrank most. The significant interaction between logs and humidity may be related to significant differences in drying rates that resulted from a combination of very high initial moisture content in the veneer and very high humidities in the drying atmosphere. This combination is probably not commonly encountered in veneer dryers.

Variations in shrinkage during drying of lumber frequently result from the development of stresses at some period during the drying cycle, commonly causing a condition known as casehardening (6). Such stresses may develop at a time during the cycle when the outer surfaces have dropped to a moisture content below the fiber saturation point and tend to shrink but are restrained by the inner bulk of wood that is still at a higher moisture content. The outer layers then become set in the expanded condition and later prevent the inner portion from shrinking freely. The greater the stresses developed, the greater may be the final reduction in shrinkage of the piece.

At first glance, the evidence of drying stresses in veneer does not appear to harmonize with earlier conclusions regarding the absence of moisture gradients during the latter part of the drying cycle. The stresses therefore probably develop at a point during the cycle when the average moisture content is still above the fiber saturation point. Figure 1 shows that a temperature gradient and hence a moisture content gradient does exist at that time. The surface layers of fibers may therefore reach the fiber saturation point before the average mois-

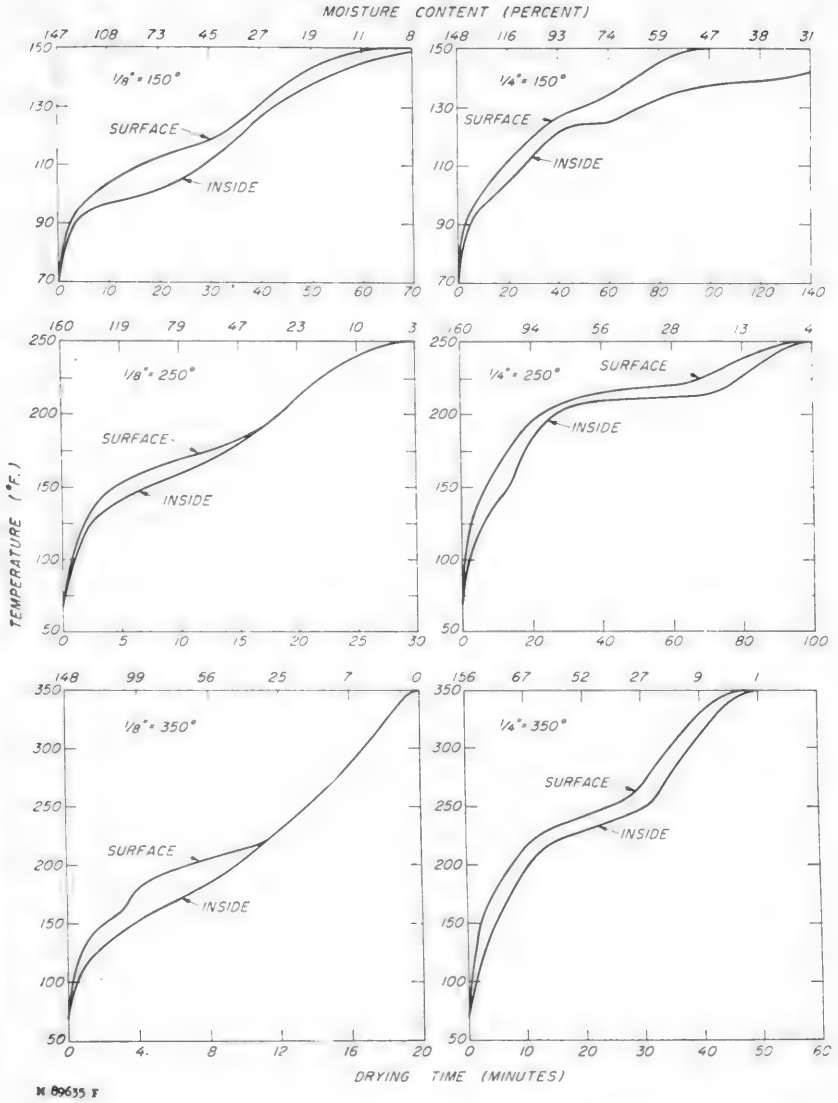


Figure 1.—Temperature and average moisture content at the surface and inside the specimens during drying. The specimens were 1/8 and 1/4 inch thick taken from yellow-poplar log 2. They were dried at low absolute humidity with 600 feet per minute air velocity at the indicated temperatures.

ture content drops that low. The surface temperature, however, then approaches the wet-bulb temperature of the drying atmosphere, which may be assumed to be 212° F. in most veneer dryers. As long as water evaporating freely from inner layers of wood passes out through the surface layers at a sufficiently rapid rate, the surface cells will be in an atmosphere of steam having a temperature of 212° F. The equilibrium moisture content of wood in steam at 212° F. is 23 percent (4), or below the fiber saturation point. Eventually there is an evening out of temperature conditions in the veneer at about 212° F. As temperatures rise higher, superheated steam is generated in the wood that moves quickly through the specimen because its pressure is above atmospheric. This rapid transfer of steam tends to eliminate any gradient through the thickness of the piece during the latter part of the drying cycle.

Therefore, from a consideration of shrinkage as well as temperature data, we are led to conclude that drying stresses in veneer originate in a rather limited critical period during the cycle; that is, shortly before the average moisture content drops below the fiber saturation point.

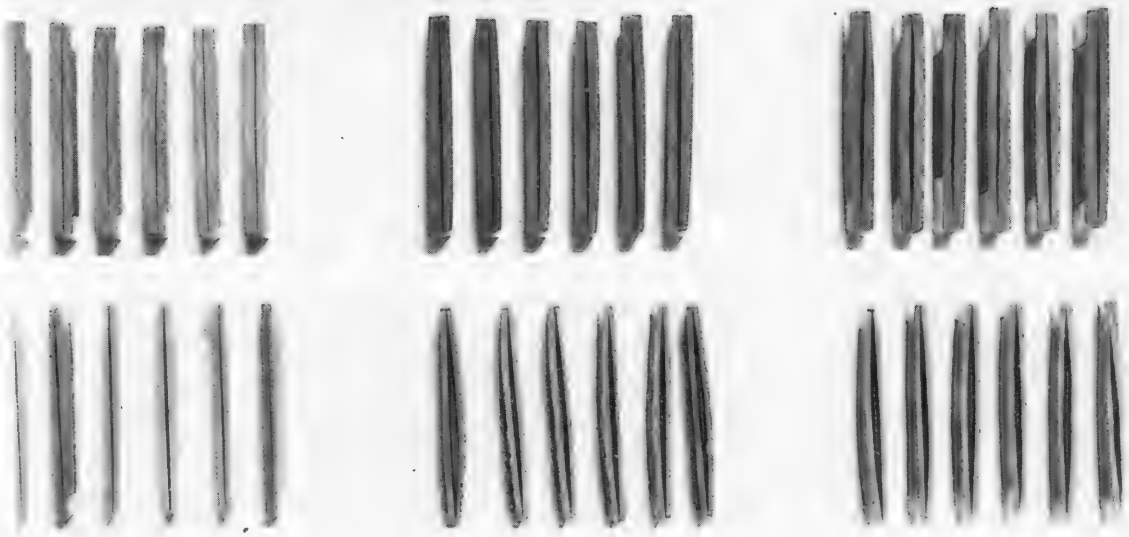
Drying defects: Figures 2 and 3 illustrate tests of the dry pieces for residual stresses. The halves of a piece that was entirely free of stresses after drying would remain flat if the piece was split open through the middle. A piece that was casehardened would yield two halves that would bow convexly outward after splitting. In the yellow-poplar specimens, as illustrated in figure 2, residual stresses were essentially absent in specimens dried at 150° F., but became progressively more pronounced as drying temperatures rose. This is in agreement with the shrinkage data presented earlier, which also indicated that casehardening stresses increased with drying temperatures.

On sweetgum specimens, however, the effect seemed to be reversed (fig. 3). In this species, severe residual stresses were present in pieces dried at the lowest temperature. At the two higher temperatures, bowing stresses were progressively less pronounced. Specimens in these two groups, however, showed honeycombing varying from slight to marked. The defect is more clearly illustrated in figure 4. Microscopic examination of the honeycombed sections showed no evidence of collapse, for there was no abnormal distortion or obliteration of the cell cavities (5). The defect appeared to be related to the weakening of the wood that may occur when green wood of some species is subjected to high temperatures. At higher drying temperatures where the stresses were greater, the temporary reduction in tensile strength of the heated wood across the grain was apparently great enough so that stress relief through internal checking could occur. This honeycombing occurred rather late during the drying cycle, probably when the wood had attained a fairly high temperature. While the existence of residual casehardening stresses in veneer may not be objectionable, the occurrence of internal checking, or honeycombing, would in many cases be considered a severe defect.

In drying tests on eucalypt veneers in a dry kiln at temperatures up to 175° F., Ellwood (2) found that buckling and splitting defects occurred before the average moisture content had dropped below 35 percent. In this species, which is also subject to collapse, Ellwood concluded that differences in shrinkage and in the development of defects were related to the degree of collapse that occurred, which in turn was affected by the temperature and humidity conditions used in drying.

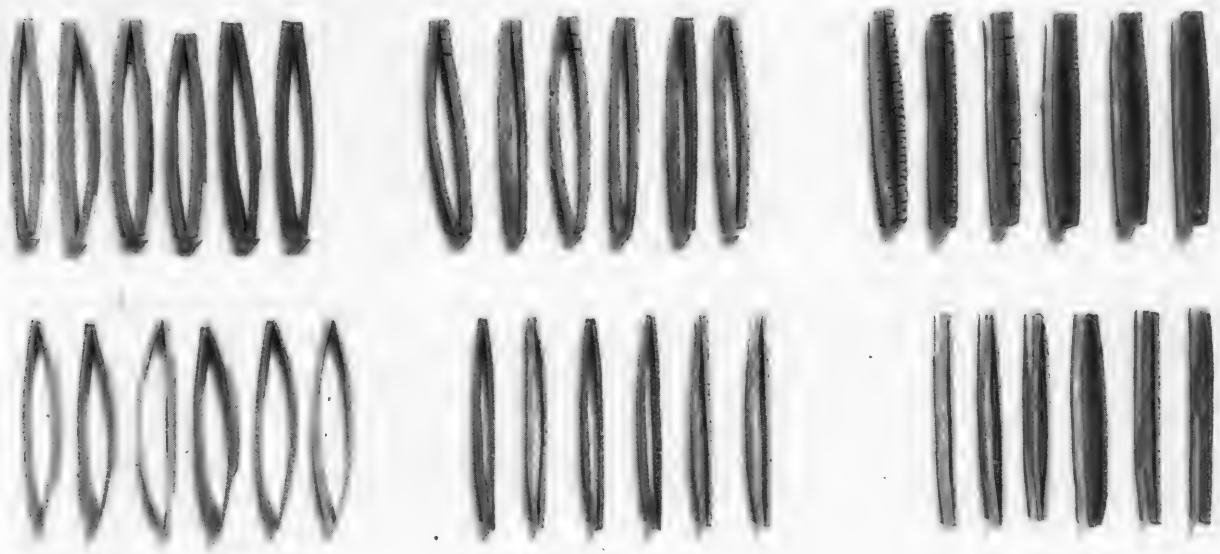
Practical Considerations

A detailed knowledge of the development of drying defects can be of great importance in connection with the design and operation of mechanical veneer dryers. Commercial operators have given some thought to possible advantages of a so-called two-stage drying system in which veneer is brought to the dry condition in two drying operations instead of one. This method would indeed



Dried at 150° F. Dried at 250° F. Dried at 350° F.

Figure 2.—The bowing of split halves of yellow-poplar pieces from log 2 indicates the degree of residual stress resulting from drying at the indicated temperatures. Pieces in the upper tier were originally ¼ inch thick, and those in the lower tier were ⅛ inch thick.



Dried at 150° F. Dried at 250° F. Dried at 350° F.

Figure 3.—The bowing of split halves of sweetgum pieces indicates the degree of residual stress resulting from drying at the indicated temperatures. Pieces in the upper tier were originally ¼ inch thick, and those in the lower tier were ⅛ inch thick.

pear to have merit, provided the relative length of the first step was such as to bring the veneer to an average moisture content only slightly above the fiber saturation point. At this point, when any moisture difference between surface and interior apparently does the most harm, an equalization period might effectively reduce shrinkage stresses.

On the other hand, one might be interested only in operating a conventional dryer in such a way as to reduce shrinkage to a minimum, while not permitting objectionable defects to develop. From this standpoint, drying under severe conditions that would promote casehardening would probably be advantageous; the only limitation being that the temperature during the latter stage must not be so high as to weaken the wood to the point where honeycombing may occur.

It is possible that high drying temperatures as well as casehardening stresses in veneer may have a harmful effect on some of the important physical properties of the veneer, such as pliability, gluability, warping, buckling, or checking. Such effects have not been clearly demonstrated as yet. On the other hand, high drying temperatures, if properly used, result in rapid drying of veneer and apparently may be manipulated so as actually to contribute to a reduction of some types of drying defects.

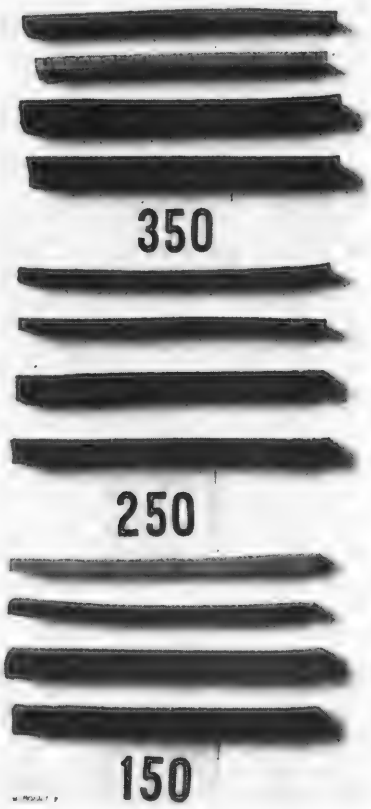


Figure 4.—These cross-sections taken at mid-length of ⅛- and ¼-inch sweetgum specimens dried at the indicated temperatures show honeycombing at the higher drying temperatures.

Table 2.--Summary of tangential shrinkage percentages of yellow-poplar averaged according to the various significant factors.

Factor[1] and level	Number of values averaged	Tangential shrinkage[2]
		Percent
Temperature 150° F.	48	6.95
" 250° F.	48	6.35
" 350° F.	48	5.82
Thickness 1/32 inch	36	6.82
" 1/16 inch	36	6.30
" 1/8 inch	36	6.54
" 1/4 inch	36	5.84
Velocity 200 ft./min.	48	6.64
" 600 ft./min.	48	6.30
" 1,000 ft./min.	48	6.18
Log No. 1	72	6.06
" No. 2	72	6.68
Log 1 x humidity 1[3]	36	6.32
Log 1 x humidity 2	36	5.81
Log 2 x humidity 1	36	6.54
Log 2 x humidity 2	36	6.84

[1] All factors listed were significant at the 1-percent level, except air velocity, which was significant at the 5-percent level.

[2] Based on green width.

[3] Low and high absolute humidity are abbreviated humidity 1 and humidity 2, respectively.

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The Purchase of Wood by Weight[1]

HAROLD S. OLSON

Manager of Wood Procurement, Wood Conversion Co., Cloquet, Minn.

Purchase method described has many advantages including better inventory control, improved buyer–seller relations, and elimination of human factor in scaling. Produce of good merchandise is rewarded while poorer grades are impartially penalized.

SINCE THE EARLIEST TIMES buyer and seller have been concerned with the methods used in arriving at a fair value for goods sold in the market or bartered for other commodities.

Inevitably, the buyer favored any method which would insure his getting the most for his money, while the seller naturally desired a method of evaluation which gave him the advantage.

Since the buyer normally controls the market, especially so in commodities of which there is a surplus, [illegible]e came to be accepted and adopte[illegible]s general practice many methods wi[illegible]h will not meet the changing conditi[illegible]ns of today's markets and commo[illegible]ty scarcities. Consequently, methods which were acceptable before are being found to be unacceptable tod[illegible]

Sometimes these old methods [illegible]e unfair to the buyer, sometimes to [illegible]e seller. Today, when a small variat[illegible]n in raw material costs may plac[illegible] manufacturer in either an adva[illegible]-

[1] Presented at meeting of the Forest Products Research Society, Upper Mississippi Valley Section, October 6, 1953, at Duluth, Minn.

geous or disadvantageous position competitively, the method of determining unit value becomes of even greater importance. There is the problem on the one hand of maintaining harmonious relations with the supplier of these raw materials, and on the other hand of stabilizing raw material cost ratios to the finished product.

In many cases those who supply raw materials to the company are also potential customers for the finished product. Thus the importance of a fair and impartial means of evaluating the raw material becomes important from another angle.

Not too long ago there were several types of log scale rules in use, some of which gave tremendous advantage to the buyer. Eventually these rules were outlawed by common consent or by statute and today we have seen them pretty well standardized.

The natural unwillingness of people to accept change and their innate suspicion of any program proposed by a large company makes progress slow and sometimes difficult, yet we are forced to progress by those with whom we compete for raw materials as well as finished goods.

About fifteen years ago the writer first realized the inadequacies of the volumetric method of determining the value of a given amount of pulpwood. Raw material use ratios to finished product were very erratic and seemed to defy any attempt at correction. This was especially true of rough aspen. While it was realized that excessive voids in the loads due to sweep, knots and other irregularities were one of the main causes of this variation, attempts by the scaler to make suitable deductions for this excess space met with considerable resistance from the suppliers with the result that it was often not possible for the scaler to make the correct deductions and still keep the supplier satisfied. Because of his position as seller, it was naturally difficult for the supplier to adopt the buyer's viewpoint on this matter and as a consequence friction was inevitable and constant.

Along with others in the industry, we were becoming increasingly conscious of the growing scarcity of raw materials and we were looking for means toward a more complete utilization of the tree. The usual method of determining the cubic volume of a cord of wood placed a heavy penalty on any stick which was below the standard top size or which varied in any way from the true cylinder on which this method of evaluation is based.

Scalers tended to penalize such wood in order to discourage its production and no doubt rightly so because of the lower yield from such wood when purchased on a volumetric basis of evaluation.

We felt that if this wood had a possible use that something should be done to salvage the material and do our share toward preventing such waste and at the same time give our producers a greater net income from their wood lots.

It was apparent that we would not be able to accomplish our aims while retaining the old fashioned method of trying to measure the volume of wood in a given lot with a rule. It was equally apparent that some method of determining the value of a given unit of wood would have to have infinite flexibility in order to meet the multitude of different conditions which presented themselves.

The human element, which presented the greatest problem, would have to be eliminated, or at least, reduced to a very minor role, if we were to accomplish our purpose while maintaining good will for our company. In an effort to resolve this difficulty, it was decided to try to find a new method of evaluation. A water immersion tank holding exactly one cord of 100" wood was constructed and tests conducted on a large number of measured cords of wood of all the species in common use at our plant, and by a wide range of average mean diameter classes. As suspected, the greatest variance was found in aspen. Cords of 5" average mean diameter aspen were found to vary from 49 cubic feet of solid wood per cord to 84 cubic feet per cord depending upon the physical characteristics of the sticks in the cord. After a considerable period of testing, it became more and more apparent that it was not possible to scale aspen by physical means and do an honest job for either the buyer or the seller. Consequently, it was decided to investigate the possibilities of new or different methods of evaluation. The possibilities of using a photographic method, of electronic scanning, of complete immersion and of weighing were considered. For various reasons all were rejected except that of weighing, which we decided to explore further.

Fair Method

It was decided that to be fair to both producer and the company that any unit figure adopted would have to be on the basis of green, winter wood, of the standard top size and specifications, timber run. With this in mind one hundred carloads of rough aspen which met these requirements were weighed, measured by the old method and the average cord weight determined. This average weight was found to be 4,764 pounds. Following this, we weighed a large number of truckloads and checked these figures against the cord figures as scaled by our scalers. The range of weight per cord as scaled was from 3,900 pounds to 5,100 pounds for green wood of similar quality to the rail wood tested. In other words, assuming a base price of ten dollars per cord, we were paying some producers $10.00 for 3,900 pounds of potential pulp making material and to others we were paying $10.00 for 5,100 pounds of the same material.

Obviously, here was one cause of our raw material variation. Equally obvious was the fact that great injustice was being done to the honest operator who was trying to deliver a good quality of well manufactured wood. He was being penalized for being honest, while the fellow who had poor wood and who practiced the usual tricks of the trade was being subsidized and encouraged.

Feeling that we owed it both to ourselves and to our suppliers to put into effect a more equitable method, if it were possible, we decided to purchase aspen pulpwood by weight effective December 2, 1946. Weighing was done at the city scales for which we paid the charge.

Supplier Reaction

At first, supplier reaction was mixed and the attitude one of suspicion, but this soon changed to one of friendly cooperation as the merits of the method became apparent. In making this change we emphasized the fact that quality wood brings a premium price and that this method is a fair and impartial one.

Since adoption of the method of purchasing wood by weight, we have not had a single complaint on scale. Prior to this, using the volumetric method, such misunderstandings were a daily occurrence.

The objectives of better supplier relationship, conservation of our forests, lesser variation of raw material costs, better inventory control as to age classes of wood and elimination of old wood as a procurement problem have been attained. Our suppliers now accept the method as the only fair one and like to sell their wood that way. We have now extended it to our rail aspen purchases and expect to buy all our wood that way as soon as we can work out the details involved.

Problems incidental to the purchase of rail wood by weight have proven to be for the most part very similar to those encountered in introducing the method in our truck area except on a larger scale.

It was deemed necessary to first explain the method to the various dealers involved, securing their cooperation and having them sufficiently grounded in the various phases so that they could carry the program to their individual producers. We found it advisable to maintain close personal liason with both our dealers and their producers during the initial period.

Not being satisfied that the tare weight as shown on the cars was correct, we adopted the policy from the first of having all cars reweighedlight on which we were using rail weights as a method of payment. We found that these car weights as printed on the railroad cars were very inaccurate and extremely variable, varying as much as 6,000 pounds and showing an average variation of about 1,700 pounds.

Shipper reaction has been favorable and a normal volume of wood was received during the period involved. Truckers like the method since they can base their charges on a weight hauled basis, getting more money for hauling the heavier woods. Private owners in our area are now selling their stumpage by weight which places the whole transaction on a weight basis, unless, of course, the stumpage is sold for a lump sum.

We hope that before too long that the county and state forestry divisions will get on the band wagon and adopt measures which will allow their stumpage sales to be handled in such a manner as to help producers to better tie in their method of purchasing stumpage with their method of selling the finished product.

Conclusion

The purchase of wood by weight allows better inventory control by allowing the exact age of the wood in storage to be known, since it comes in green; it encourages prompt delivery of wood to the plant, thus eliminating the former problem of what to do with wood left over from the previous season and still undelivered, (so called "distress wood"), it eliminates the unknown factor in wood procurement relating to the amount of wood in the woods which the mill feels obligated to take, it tends to equalize and stabilize deliveries, thus working toward lower wood handling costs at the plant. It eliminates the human factor in scaling and rewards the producer of good merchandise while penalizing the poorer grades but always impartially and without causing controversy. It allows better utilization of the tree, thus conserving timber. Raw material costs are better stabilized since each dollar spent for pulpwood buys a much more uniform amount of pulping material.

Supplier and purchaser tend to work together more harmoniously and the company benefits from this in many ways.

Seasonal variations are comparatively slight and come at a time when wood deliveries are normally low, and in any case, tend to balance out over the year, since price is set on a green wood, winter weight basis.

The Effects of Moisture Content and Machining of Wood on R. F. Gluing Processes

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The moisture content and machining of wood are factors which must be controlled in all gluing work. However, in r.f. gluing processes these variables have additional effects on the electrical properties and behavior of the wood-glue combination. The theoretical and practical aspects of problems arising from lack of control or know-how of these factors are discussed and recommendations are made to enable the user of r.f. gluing equipment to minimize their effects on the r.f. gluing process.

Introduction

THERE ARE SEVERAL FACTORS common to all electronic gluing operations. Of major importance are:

1. Type of r.f. generator and output power rating.
2. Operating frequency of the generator.
3. Press and electrode design and construction.
4. R.f. tuning circuits for load matching.
5. Shielding of the press and generator.
6. Type and make-up of the glue.
7. Moisture content of the wood.
8. Machining of the wood parts to be glued.

The answers to the questions raised by items one through five are usually furnished by the manufacturer of the r.f. equipment through his engineering and technical sales departments. Similarly, the use of a particular glue or glue mixture is based on the recommendations of a manufacturer of adhesives. However, the moisture content of the wood and the type and quality of the machined surfaces to be glued are problems which the user of the equipment must solve. It will be the purpose of this paper to examine the technical aspects of these latter two factors and to discuss their effects on the r.f. gluing process.

Moisture Content

Moisture in wood is of constant concern to everyone making, selling or using products made of wood. Ordinarily, it is the effect of moisture in wood on its strength, decay resistance or stability in furniture and other wood products that concerns us. In r.f. gluing we add to this list by acknowledging that moisture in wood greatly influences its electrical properties. For instance, several investigators (1,7) have found that the DC resistance of wool varies widely over the range in moisture content from oven-dry to the fiber saturation point. Based on this phenomenon several different types of moisture detecting devices have been developed. If we restrict our consideration to the behavior of wood-moisture relations at radio frequencies, we find from the data of Skaar (6) and others (3, 4, 9, 11) that once again moisture in wood not only exerts a pronounced effect on its resistance but also affects other electrical properties such as dielectric constant, power factor and

Table I—THE DIELECTRIC PROPERTIES OF WOOD PERPENDICULAR TO THE FLAT GRAIN SURFACE IN RELATION TO SPECIES, MOISTURE CONTENT AND DENSITY AT SEVERAL RADIO FREQUENCIES

Species	Specific Gravity	Moisture Content	Dielectric constant			Resistivity in megohm-cm.[1]			Power Factor[1]			Source of data
			2 mc.	5 mc.	15 mc.	2 mc.	5 mc.	15 mc.	2 mc.	5 mc.	15 mc.	
(All species)	0.40	5	2.2	----	2.1	10.0		1.0	0.037	---	0.048	Skaar (6)
(All species)	0.40	10	2.7	----	2.6	7.0		0.7	0.040	-----	0.062	Skaar (6)
(All species)	0.40	15	3.3	----	3.2	3.0		0.5	0.080	-----	0.076	Skaar (6)
(All species)	0.50	5	2.5	----	2.4	-	-		---	-----	-----	Skaar (6)
(All species)	0.50	10	3.2		3.0	--			-----	-----	-----	Skaar (6)
(All species)	0.50	15	3.9	----	3.7	----						Skaar (6)
(All species)	0.60	55	2.8	----	2.6							Skaar (6)
(All species)	0.60	10	3.6	----	3.4	--	---	----	-----	-----	-----	Skaar (6)
(All species)	0.60	15	4.5	----	4.3							Skaar (6)
Douglas fir	0.45	5	2.08	1.99	1.94				0.036	0.045	0.051	Wittkopf
Douglas fir	0.45	8	2.28	2.20	2.15				0.039	0.049	0.060	and
Douglas fir	0.45	12	3.10	3.04	2.98		----	----	0.040	0.048	0.061	MacDonald (10)
Douglas fir	0.55	5	2.38	2.30	2.24				0.042	0.052	0.061	"
Douglas fir	0.55	8	2.65	2.56	2.49				0.042	0.055	0.067	"
Douglas fir	0.55	12	3.37	3.28	3.23				0.041	0.048	0.062	"
Douglas fir	0.65	5	2.64	2.54	2.48				0.044	0.055	0.063	"
Douglas fir	0.65	8	2.93	2.83	2.76				0.040	0.052	0.067	"
Douglas fir	0.65	12	3.72	3.65	3.59				0.037	0.045	0.061	"
Yellow birch		5	----	2.9					----	0.048		Miller and
Yellow birch		10	----	3.8					---	0.052		Peterson
Yellow birch		15		5.3						0.059		(4)

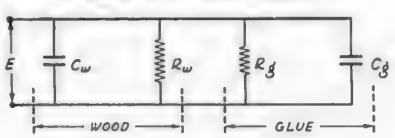
[1] The values fo resistivity and power factor given by Skaar (6) represent average values for all species and density classes.

loss factor. Examples of the variations to be expected in the r.f. properties of wood with moisture content are given in Table I.

From a practical viewpoint, we are held to a certain limited range of moisture content in wood for most gluing operations. For furniture and other wood products to be used indoors, a moisture content from 5% to 10% represents the range to be expected for wood in service or use. Therefore, we try to do our gluing within this range so that we will minimize any "built-in" stresses in our wood products. We have also learned through experience that the most commonly used furniture glues (urea formaldehyde, animal and polyvinyl) behave well over this limited range of moisture content. The advent of electronic gluing techniques has not placed any additional restriction on our free use of wood within this normal moisture range. However, a wood-glue combination will be cured in an r.f. field only when we are able to develop sufficient heat in the glue to cure or set it. Consequently, for an edge gluing operation where we are endeavoring to make maximum use of the phenomenon of selective or glue line heating, the moisture content of the wood is of paramount importance.

As shown in Figure 1, a wood-glue load can be represented in simplified form by a combination of resistances and capacitances. For edge-gluing and most assembly gluing operations the equivalent parallel circuit more closely approximates the conditions which exist. Since both the resistance and capacitance of the wood will vary with moisture content, a corresponding change will occur in the over-all characteristics of the load. In a series of tests made at the College (12) the variations in the effective parallel resistance of edge-glued 4″×4″×1″ basswood panels with moisture content were determined. The results are given in Table II which indicates the changes in the electrical properties of the wood, the glue and the wood-glue combinatioin containing one glue joint at 5, 10, and 15 percent moisture content for operating

EQUIVALENT PARALLEL CIRCUIT



EQUIVALENT SERIES CIRCUIT

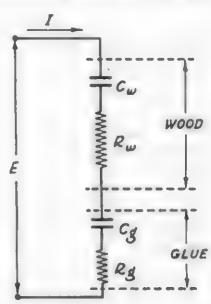


Figure 1.—The equivalent electrical circuits of a wood-glue load (A) in parallel, and (B) in series, where:

E = R.F. voltage across the wood-glue load
I = R.F. current through the wood-glue load
C_w = Capacitance of the wood
R_w = Resistance of the wood
C_g = Capacitance of the glue
R_g = Resistance of the glue

frequencies of 5, 10 and 15 megacycles per second. A rather large decrease in resistance in both the wood alone, and of the wood-glue combination occurred when the moisture content was raised from 5% to 10%. On the other hand, the change in equivalent resistance above 10% in moisture is markedly less, especially at the higher operating frequencies.

Table II—VARIATIONS IN THE EQUIVALENT PARALLEL RESISTANCE OF 4″ x 4″ x 1″ BASSWOOD PANELS (ONE GLUE JOINT) WITH MOISTURE CONTENT

Operating frequency in megacycles	Moisture Content in percent	Resistance in ohms	
		Wood	Glue
5	5	120,000	40,000
5	10	60,000	20,000
5	15	40,000	18,000
10	5	80,000	30,000
10	10	30,000	15,000
10	15	20,000	15,000
15	5	36,000	26,000
15	10	18,000	12,000
15	15	12,000	12,000

The effect of moisture in wood on its electrical behavior also is indicated by the theoretical and empirical equations which have been developed to measure r.f. power input into a load. For instance, the basic power equation in r.f. heating as given by Terman (8) is

$$P = 1.41\ E^2\ f\ \epsilon'' \text{ watts/cu. in.} \quad (1)$$

where E = r.f. voltage gradient in kilovolts per inch
f = operating frequency in megacycles per second
ϵ'' = loss factor (ϵ'' = power factor × dielectric constant)

An examination of this theoretical equation indicates that the r.f. power absorbed by the wood will vary directly with its power factor and dielectric constant. These properties in turn vary with moisture content as shown in Table I. Similarly, the empirical equation for electronic edge-gluing given by Winlund (10) indicates moisture content of wood to be one of the main factors to be considered. The equation is

$$P\ T\ A = 18\ G + M\ W \quad (2)$$

where P = r.f. power in K W
T = duration of heating cycle in seconds
A = correction factor based on electrode design and wood species
G = glue line area in square inches
M = moisture content of the wood in percent
W = volume of the wood in cubic inches

Press: Electrodes:	Batch Staggered	Batch Solid	Continuous Staggered	Continuous Solid
A = (Softwoods:	100	80	94–118	94
A = (Hardwoods:	56	44	52– 65	52

The practical significance of the changes in electrical properties brought about by variations in moisture content may best be interpreted in terms of their effects on the distribution of r.f. power in the wood-glue load. In every electronic gluing process based on selective heating of the glue lines, we attempt to put maximum power into the glue and dissipate a minimum of power in the wood. Recalling that in r.f. edge-gluing or assembly gluing, the wood and glue form parallel resistance paths, we may write

$$P = \frac{E^2}{R_p} \qquad (3)$$

where P is the r.f. power in watts, E if the r.f. voltage and R_p is the effective parallel resistance of the material under consideration. If, as shown in Table II, the effective parallel resistance of the wood at 5 megacycles and 5% moisture content is about three times the resistance of the glue line, the power dissipated in the wood is one-third of that heating the glue. In other words, 75% of the total available r.f. power is heating the glue and 25% is being lost in the wood.

This effect may be indicated mathematically as follows:

$$P_t = P_w + P_g = \frac{E^2}{R_w} + \frac{E^2}{R_g}$$

where P_t = Total r.f. power in watts
P_w = R.f. power used in heating wood
P_g = R.f. power used in heating glue

At 5 megacycles and 5% moisture content

R_w = 120,000 ohms
R_g = 40,000 ohms
or $\frac{R_w}{R_g} = \frac{1}{3}$

Then $P_w = \frac{E^2}{3}$ and $P_g = \frac{E^2}{1}$ or $\frac{P_w}{P_g} = \frac{\frac{E^2}{3}}{\frac{E^2}{1}} = \frac{1}{3}$ or $P_g = 3\,P_w$

At a moisture content of 10%, the resistance ratio is still essentially the same, which means that the power dispersion remains the same. However, at a moisture content of 15%, the resistance of the wood is only a little over twice that of the glue so that of the total r.f. power about 67% is heating the glue and 33% is now lost in the wood. This trend is accentuated when the operating frequency is increased so that at 15 megacycles per second the division of power is almost equal between the wood and the glue. Thus we see that there is a definite advantage in limiting our moisture content to about 10% or less. The higher degree of selective glue line heating at 5 megacycles also indicates the reason for most edge-gluing units being operated at this frequency or lower.

Peterson (5) found that for a yellow birch panel having about 240 square inches of glue line area, the r.f. power required for edge-gluing at 20% moisture content may be as much as 100% greater than that required for a panel at 6% moisture content.

Machining of Wood

As in the case of moisture in wood, the machining requirements for r.f. gluing do not differ markedly from those usually prescribed for good gluing practice regardless of the curing method employed. As Marra (3) forcibly pointed out, other methods of gluing "may appear to tolerate poorer gluing practices" than does r.f. gluing; however "there is no substitute for good practice and bonds made under unfavorable conditions by any method may be expected, sooner or later, to give unsatisfactory service."

Assuming that we are not so unrealistic as to expect an r.f. gluing procedure to provide a cure-all for poor gluing practices, we may then say that the machining requirements for electronic edge-gluing are identical to those required of any edge-gluing operation, namely:

1. The wood must be free of warp and twist.
2. The edges must be square and straight.
3. The thickness must be fairly uniform.
4. The machined surfaces must be smooth and free of torn or loose wood fibers.
5. The moisture content must be uniform and within the range required for the particular product.

Again, as in the case of moisture in wood, there are some electrical effects due to machining which are not considered in ordinary gluing operations. For instance, when the edges of boards to be edge-glued are out of square, tight and durable glue joints are impossible under any gluing technique. However, in electronic edge-gluing an added factor, that of a non-uniform voltage drop across the glue line exists. As Winlund (10) has indicated, this may result at least in a disproportionate increase in heating time for satisfactory gluing, and many times will actually preclude curing of the glue. Research at the College (13) has shown that machined surfaces having ridges or grooves due to nicks or burrs on the jointer knives are a primary factor in r.f. burning. This phenomena is also affected by the anatomy of the wood on the machined surfaces. In softwoods and diffuse porous hardwoods having a band of denser fibers in the summerwood portion of an annual ring, this region of denser fibers may show greater swelling when wet by the glue, thereby creating natural ridges on an edge surface. The electrical effect of a ridge along an edge surface is to set up a region of high resistance which in turn results in an undesirably high voltage gradient across this region. An internal burn which extends along the length of a glue joint results from this excessive voltage gradient.

In many electronic edge-gluing operations, the individual boards are cut to rough length, hit-or-miss planed and then jointed or glued directly from a straight-line rip saw. The variations in thickness which exist usually are slight (less than 1/8") and do not cause trouble. However, the electrical effect of one or more thin boards in a panel is to create an air-gap directly above one or more of the glue joints. A voltage drop will occur across this air gap which may reduce the voltage across the glue line to the extent that only a partial cure of the glue results. Such a panel often falls apart when taken from the press. A similar effect may result from one or more boards in a panel having an excessive moisture content or if the edges of the boards deviate from a straight line. In this way, an electronic press may at times be termed "self-inspecting". Unfortunately, the built-in stresses which are set up in panels having poorly machined surfaces may not result in glue line failure until the product is in service. Consequently, it is not possible to over-emphasize the statement that only through constant surveillance and control of moisture and machining techniquees can high quality glue joints consistently be obtained.

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Some Aspects of the Influence of Rays on the Shrinkage of Wood*

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Investigations are described which show that in red oak, wood surrounding broad rays shrinks radially almost twice as much as do the broad rays. Illustrations substantiate distortion caused.

THE HYGROSCOPICITY OF WOOD, that is, its change in moisture content in response to change in the relative humidity of the surrounding atmosphere, is a characteristic of prime importance to the wood-using industry. In response to changes in moisture content, wood has the faculty of changing its dimensions, and this is a property of wide economic significance. Lumber green from the saw is unsuited for most uses and must be dried—naturally or artificially—to a moisture content compatible to that which it will encounter in service. In this process of seasoning, defects often develop which result in the degrading of the lumber. Even after manufacture, products may become distorted in shape, furniture may loosen at the joints, doors and drawers may jam, because of the change in the relative humidity of the air and its effects upon the dimensions of the wood.

Numerous defects arising during or after manufacture can be attributed to the difference in shrinkage in the longitudinal, radial, and tangential directions. Longitudinal shrinkage of wood is normally very small and is usually disregarded. Transverse shrinkage, however, is comparatively large, with the average tangential shrinkage nearly twice as great as the shrinkage in the radial direction.

The cause of difference between the longitudinal and transverse shrinkage as related to the organization and arrangement of cellulose within the cell wall has been described in numerous books and reports and, recently, has been reviewed by Pentoney (6). It is the purpose of this paper to mention briefly the existing theories which attempt to explain the difference between radial and tangential shrinkage of wood and to report the results of preliminary tests undertaken at the Ottawa Laboratory of the Forest Products Laboratories of Canada, to determine the effect of the structure of wood on the dimensional changes which occur in response to changes in moisture content.

Transverse Shrinkage Theories

Many references appear in literature to the long-standing explanation that rays—arranged radially and perpendicularly to the vertical cells—restrict wood shrinkage in a radial direction. The assumption has been that the ray cells shrink only a small amount in their longitudinal direction (radially in the wood) thus reducing the radial dimensional change but not limiting the shrinkage in the tangential direction.

Reports by Greenhill (3) (4), Barkas, (1), and Clarke (2) support the ray-restraint theory. However, Kollman (5) rejected the theory that the difference between radial and tangential shrinkage is attributable to the rays, on the basis of the tensile strength of the rays during swelling.

Ritter (7) and Ritter and Mitchell (8) (9) have taken exception to the ray-restraint theory after estimating the fibrillar orientation in ray cells of basswood by means of polarized light, by measurement of shrinkage of pine blocks from which the rays were said to have been "removed by special degradative action", and other tests. They state (9) that "ray cells have no restraining effect on the radial shrinkage of wood", and further that "ray cells may be omitted from among the various factors that cause less radial than tangential shrinkage of wood". They have come to the conclusion that the shrinkage of ray cells, in a radial direction, is similar to the radial shrinkage of wood from which they were isolated, and that the difference between radial and tangential shrinkage is caused by the slope of the fibrils around the bordered pits on the radial walls of the vertical cells.

Other theories are based upon the interaction of the shrinkage of spring-

*Contribution of the Ottawa Laboratory of the Forest Products Laboratories of Canada, Forestry Branch, Department of Northern Affairs and National Resources, Ottawa, Canada. This work was undertaken in co-operation with members of the Department of Wood Technology, State University of New York, College of Forestry, at Syracuse.

wood and summerwood, the difference in slope of the fibrils in the radial and tangential cell walls, and the difference in amount of middle lamella present per unit length in a radial and tangential direction. These theories were included in the review by Pentoney (6) and are not described in detail in this article. It is of interest to note, however, that in shrinkage tests conducted on isolated and non-isolated springwood and summerwood of Douglas fir, Pentoney concluded that differential transverse shrinkage was primarily the result of springwood-summerwood interaction, in that the tangential shrinkage of wood was about the same as the tangential shrinkage of isolated summerwood while, radially, the shrinkage of the wood approached an average of the shrinkage of the springwood and summerwood.

Since contradictory statements have been published as to the effect of rays on restraining the radial shrinkage of wood, tests were undertaken by the author to determine the shrinkage of rays when removed from and when partially isolated from the surrounding wood. Red oak *(Quercus borealis* Michx.F.) was selected as the material for test since the wood of this species contains broad rays of a size which can be relatively easily removed or exposed for shrinkage measurements.

This paper describes the material tested, the method of obtaining shrinkage measurements, and the results with regard to the difference between radial shrinkage of broad rays and of wood —containing fine rays—with broad rays removed. Results of shrinkage tests of material containing broad rays are also reported.

Material and Methods of Testing

Wood used for the study was taken from a red oak tree (13.5 inches d.b.h.-o.b.) felled in December 1952 at the Petawawa Forest Experiment Station in Ontario. Bolts cut from the tree were immediately transported to the Forest Products Laboratory, Ottawa, and placed in water storage to avoid drying. By keeping test material in a water-saturated condition, the danger of permanent drying stresses developing before shrinkage measurements were made was eliminated. A cross-section of the trunk (about 3 inches along the grain) was cut a little above stump height level to provide material for the tests.

Specimens described in this report were limited to wood from the east side of the tree and, for the most part, to wood of a uniform rate of growth formed from 1946 to 1950. Since comparison of the amount of radial shrinkage of broad rays to that of wood without broad rays was the object of the tests, investigations were confined to wood from one position within the tree so as to eliminate any variability which might occur if wood were taken from different locations within the tree.

In order to separate the broad rays from the surrounding wood for the measurement of dimensional change, transverse sections about 80 microns in thickness were cut from small saturated blocks. Care was taken in cutting sections so that pressure of the microtome clamp was not applied near the material to be used for subsequent testing. At all times, the blocks and sections were kept in water-saturated condition.

Sections, or parts of sections dissected by means of a scalpel on glass slides, were kept wet and covered with a cover glass while being measured in the saturated condition. Measurements were made by means of a travelling microscope reading to 0.01 mm. After measurements at saturation were recorded, the cover glasses were removed to allow the sections to dry in air without restriction. Further drying was accomplished in desiccators over phosphorous pentoxide. Finally, the specimens on glass slides were covered with cover glasses, which were taped to the slides, and supported near the top of a desiccator containing phosphorous pentoxide and fitted with a plate glass top. Measurements of the sections in the dry condition were made through the plate glass desiccator top by means of the travelling microscope.

Results and Discussion

1. **Radial Shrinkage of Broad Rays:** As previously mentioned, in order to determine the amount of radial shrinkage of broad ray tissue compared to that of the surrounding wood, broad rays and radial strips with no broad rays included (separated from between broad rays) were dissected from saturated transverse sections 80 microns in thickness and the radial shrinkage measured. The results of these measurements are shown in Table 1. It will be noted that the radial shrinkage of broad ray tissue is about one-half that of wood without broad rays but with fine rays present.

In order to obtain preliminary information on the effect of broad rays on the shrinkage of wood, transverse sections—about 1 cm. in radial length —were prepared each containing a broad ray on both radial edges of the sections. Measurements of radial shrinkage made along the rays on each side (designated "a" in Table 2) and along the central wood, halfway be-

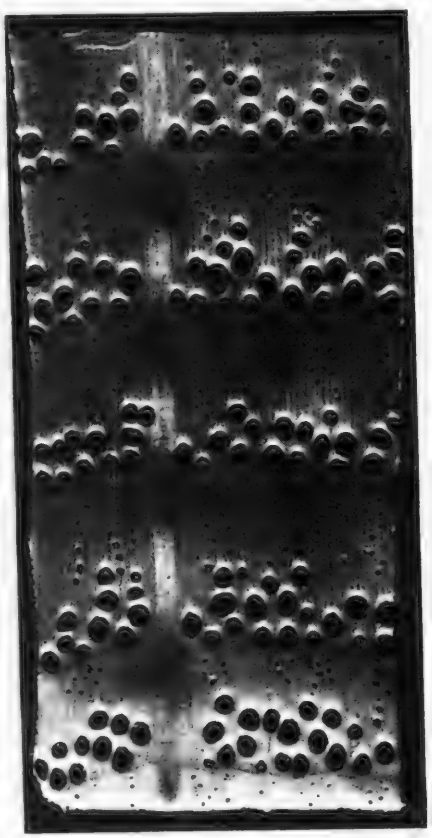

Figure 1.

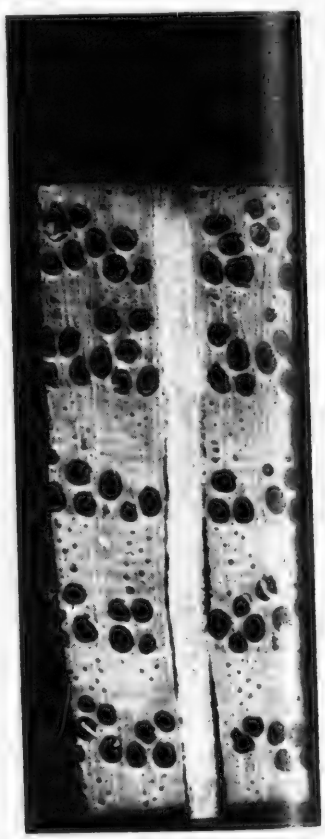

Figure 2.

Table 1—RADIAL SHRINKAGE OF BROAD RAYS AND OF WOOD WITHOUT BROAD RAYS

Material* Measured	Number of Specimens	Mean Radial Shrinkage (% of saturated dimensions)	Standard Deviation
Wood without broad rays	60	4.83	0.22
Broad rays	11	2.59	0.18

*Transverse sections 80 microns in thickness.

tween the broad rays (designated "b" in Table 2), showed that the central portion shrank more than the edges where the rays restrained the dimensional change. In some of the ray-bounded sections, wood between the broad rays was isolated by dissection and its radial shrinkage was measured along the same line of measurement previously employed in the centre of intact sections. The shrinkage of such isolated wood, freed from the influence of broad rays, was significantly greater than that shown by wood in sections with broad rays along their edges. The results of these measurements are shown in Table 2.

A statistical comparison of the data presented in Table 2 has shown a highly significant difference between the mean radial shrinkage values for the three groups of test material. The results clearly show that, in the specimens studied, the broad rays not only shrank less radially than did the surrounding wood, but the rays reduced the shrinkage of the wood in a radial direction.

Radial sections (80 microns in thickness) of broad ray tissue were prepared in order to compare the radial shrinkage of such sections with the radial shrinkage of broad rays isolated from transverse sections. The results indicate an average radial shrinkage of ray tissue of 2.36 per cent. Statistical comparison of the mean radial shrinkage of broad ray tissue from radial sections and isolated from transverse sections has indicated that the difference is barely significant at the 5 per cent level of probability, and thus there may be no difference in the radial shrinkage of broad rays isolated by the two different methods.

2. **Distortion of Transverse Sections:** When saturated transverse sections of red oak containing a broad ray were allowed to dry, the dried sections showed a series of waves which originated in the broad ray. This deformation of the ray seems undoubtedly to have been caused by the fact that the radial shrinkage of the surrounding wood is greater than that of the broad ray. This is illustrated in Figure 1 which is a photomicrograph (magn. X 12) of a transverse section of red oak dried under normal room atmospheric conditions.

When broad rays are partially isolated from the surrounding wood in a saturated transverse section, the difference in shrinkage between the rays and the rest of the wood is even more plainly visible when the section dries. A photomicrograph taken of a specimen dried under normal room atmospheric conditions, as shown in Figure 2, illustrates the difference in radial shrinkage between the broad ray and the surrounding wood. Figure 3 also shows the deformation which takes place when a broad ray is partially isolated. The specimen in this photo is a transverse section, 80 microns in thickness, dissected while saturated so that a broad ray was present along one radial edge and wood along the other. Partial separation of the wood from the ray was made with a scalpel. When the section was allowed to dry in the air, the bow-shaped deformation resulted because of the greater radial shrinkage of the wood than that of the broad ray.

The curvature that results on drying a strip composed of two materials, combined edge to edge, and characterized by different dimensional change properties is shown in Figure 4. The photomicrograph is of a narrow transverse section containing fibrous wood tissue on one edge and broad ray tissue on the other, and allowed to dry under normal room atmospheric conditions. The curvature which developed in the strip indicates that there

Figure 3.

was less shrinkage in the broad ray tissue than in the wood beside the ray.

Figures 5 and 6 are included to show curvature similar to that in Figure 4 caused by the difference between the shrinkage of the broad ray and that of the surrounding wood. Figure 5 illustrates a transverse section at saturation which has been divided into three parts so as to separate the central wood (without broad rays) from the lateral strips, each of which is a separate portion with broad ray tissue included along its outside edge. Figure 6 shows the same portions of the section, as in Figure 5, in the air-dry condition. Curvatures of the outer strips indicate that less radial shrinkage has occurred in the broad ray than in the fibrous wood. The fibrous edge of all sections of this type was in every instance the edge that underwent the most shrinkage in drying, the ray in such sections always being on the convex edge.

Table 2—RADIAL SHRINKAGE OF WOOD WITH BROAD RAYS ATTACHED AND OF BROAD RAYS WITH WOOD ATTACHED, COMPARED TO RADIAL SHRINKAGE OF WOOD WITHOUT BROAD RAYS

Test Material*	Number of Specimens	Mean Radial Shrinkage %	Standard Deviation
a) Broad rays with wood attached	20	3.79	0.27
b) Wood between broad rays	8	4.32	0.24
Isolated wood without broad rays**	17	4.87	0.18

*Transverse sections 80 microns in thickness.
**Specimens freed from broad rays by dissection.

Figure 4.

Figure 5.

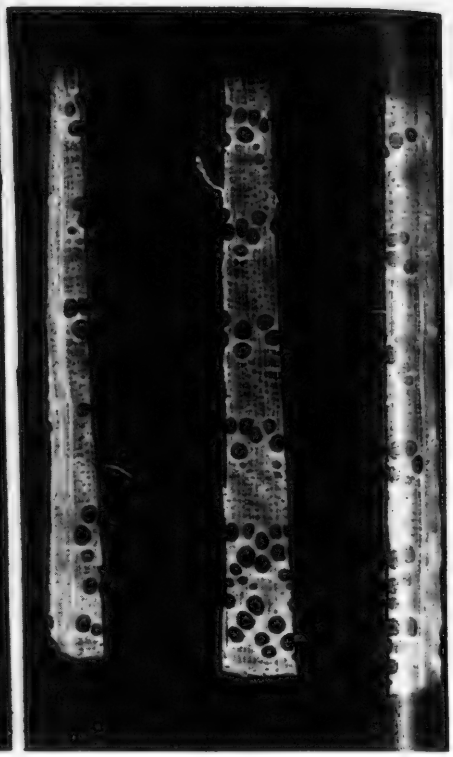

Figure 6.

Summary and Conclusions

The results of investigations described herein show that in red oak, wood surrounding broad rays shrinks radially almost twice as much as do the broad rays. The significant effect of broad rays in restricting the radial shrinkage of specimens tested has also been shown. This has been further substantiated by illustrations of the distortion caused in drying sections in which broad rays have been partially isolated from the surrounding wood.

Since fine rays present in the "surrounding wood" referred to in this article may have dimensional change properties similar to those of the broad rays, they may also be effective in restraining the radial shrinkage of wood. Tests have been undertaken in an attempt to determine the effect of fine rays on the radial shrinkage of red oak and to arrive at a theoretical value for the radial shrinkage of the wood without rays. The results of this phase of the investigation, as well as information on other species, will be published at a later date.

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Correlating Evaluation Tests of Wood Preservatives[1]

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The author stresses a four point evaluation program involving laboratory tests, test plot exposure of small stakes and round posts, and documented service tests of treated commercial units. Test methods are discussed and sample current tests are examined for significance and possible correlation of the test results. Laboratory soil-block cultures yield results that can apparently be correlated with test plot and pole line experience with creosote. The soil-block test can be used to determine preservative threshold retentions, i.e., how much of a given preservative must be retained by the wood at treatment to insure preservative effectiveness.

Laboratory and correlated test plot experiments should be supplemented when practicable with documented tests of commercial units.

THIS IS MORE AN ESSAY on policy and planning than a presentation of technical data. It is really an argument for a realignment and a change in overall viewpoint about evaluation procedures. In a number of instances the writer or his colleagues (7, 16) have stressed the broad concept of evaluation of preservatives for ground contact use that involves (a) laboratory tests, (b) outdoor test plot experiments with stake specimens, (c) test plot experiments with fence posts or with service-size specimens, e. g. pole-diameter posts and (d) documented service tests. Such a concept projects the evaluation process from the present—represented by the laboratory test—far into the future toward some end point representing either terminatiton of an economic service life, or actual failure because of deterioration by biological agents. Dynamic mechanical damage is excluded. Intrinsically implied in such a concept is some semblance of integration and correlation. Until recently it has been difficult to approach the inherent problems on a practical basis. The development of the soil-block test procedure appears to make it possible to plan the whole evaluation program more rationally than ever before.

The words "correlating" and "correlation" as used here have a standard dictionary definition, i. e., they mean bringing into reciprocal relation, with a sense of equivalence, or concordance, or interdependence. The reader will keep clearly in mind the difference between mere comparison and correlation. An attempt will be made to present evidence of correlation or lack of correlation within the present evaluation systems, and to develop a plan for insuring better correlation in the future.

A four-point program like the one outlined above, since it requires interpretation and appreciation of each individual part, minimizes over-exaggeration of the service test without detracting from its relative importance in the whole scheme. It is quite impracticable to ignore the inferences to be drawn from past experience. It appears to the writer to be equally impractical, as well as illogical, to make past experience an over-stressed criterion for judging the probable value of a wood preservative for present day use. Incidentally, many records of long life of treated timber are simply interesting accounts of service life, satisfactory and confirming evidence justifying the hope and expectancy of some earlier engineering plans and decisions. Except in the broadest sense, unless the units are branded properly and unless accurate information is available on the character of the timber, and on treatment, preservatives and retention, such records do not qualify as service tests in the sense of this paper.

Logically, the consumer of treated wood products should be able to secure an effective preservative, in adequate quantity, in wood that is properly treated to insure the permanence of his property, within reasonable and practical estimates of required service life. Actually the treated timber he buys should ideally be so well preserved that a) early replacements are reduced to a minimum and that b) the *physical life* of the treated timber is longer than the *service life* of the plant or structure. If the consumer works his problem down to basic considerations, the question he is likely to ask himself and his potential supplier is "How much preservative should I buy to insure an economic service life?"

The utilities engineer may or may not know much biology, but he is intently aware that early failure by decay means relatively high early maintenance charges. He is also trained to think in terms of appropriate factors of safety, and he is therefore likely to think first of essentially permanent protection against decay under severe or very severe exposure conditions; and he then can adjust his treating specifications, at his own risk, by lowering retention requirements where the chance of attack by biologic enemies has proved to be below the calculated maximum hazard.

To write such end-use specifications intelligently the engineer, either consciously or subconsciously, must attempt to correlate the results of experience and the results of experiment. He cannot depend wholly on experience, represented by the "service test" of treated timber in his own or his colleague's utility plant, mainly because of the continuously changing characteristics of the timber supply and the introduction of new preservatives. He has been made conscious of the rapid development and application of quality control for regulating manufacturing procedures; which implies the use of laboratory tests of materials, plus inspection of manufacturing processes, that will assure conformance of the finished product to the customer's specifications.

In continued production and product reputation, whether of Benson's (2) machine gun cartridges or of treated wood poles, some more tangible measuring stick than tradition must be applied. This is written without any intention of questioning the reputation, as such, of any good, well-preserved wooden product. But reputation and tradition are seen dimly, like a faded daguerreotype, by some of the younger generation of engineers and procurement agents who must be shown that the tradition—and the faith—are well founded. Benson, suggesting that the service test measures customer reaction or customer evaluation, rightfully stresses the point that laboratory tests and quality control

[1] Presented for presentation before the Society for Industrial Microbiology, Madison, Wisconsin, Sept. 8, 1955.

measures must be developed with due regard to the actualities of service.

One hears the opinion frequently expressed that the laboratory test—the soil-block test for example—cannot imitate actual service conditions. Such an opinion is, of course, basically true as a broad generalization; but it would not necessarily hold for some of the important factors of outdoor exposure that bear on the resistance or susceptibility of treated wood to decay. In a slightlty different direction, one is warned that the results of laboratory tests cannot be used as a basis for estimating the expected average life of treated wood. The general truth of this statement may also be granted. However, it does not seem necessary to charge the laboratory investigator with the responsibility of developing methods of complete imitation of outdoor exposure or of calculating life expectancy.

Based on observation and experience with the laboratory soil-block test over the last decade the writer believes that the test can be used to determine under severe but controlled conditions *how much* creosote, or pentachlorophenol, or copper naphthenate, or sodium fluoride for example, must be retained by the wood at the time of treatment to prevent critical, appropriate wood-destroying fungi from attacking the treated blocks. The application of the test results depends among other things on better knowledge and definition of service conditions, or biological and other factors.

The principal biological problems that affect the planning of an evaluation procedure are those related to the wood-destroying fungi themselves and to the conditions governing their growth, along with their companion molds, bacteria, protozoa, and other animal agents. Among the most important of these problems are those involved in the isolation, laboratory culture and identification of the really critical organisms that occur on or in treated wood, both in service and in the test plot. The phrase "on or in treated wood" means that the fungi are actually decaying the treated wood, or that they are growing on untreated sapwood or heartwood beneath an outer treated shell. The fungi that attack *untreated* wood may or may not be important because many of them may be sensitive to, and therefore easily controlled by, the preservative or preservatives under investigation. General climatic and weather conditions, since they affect the activity of fungi and other biologic organisms, will have much to do with the performance of a wood preservative.

The requirements for a good wood preservative have been listed, discussed, and guarded with words of solemn warning over and over again (4, 13, 23). As a matter of practical research planning it must be assumed that questions or doubts about general fungicidal properties, toxic hazard to humans, flammability, corrosiveness, penetrating ability, availability and relative costs will have been reasonably well settled *before* a program of *preservative* evaluation is started. This means that the materials to be tested have been passed through the preliminary laboratory stages, or through some experience, and have been judged to have potential or real value as wood preservatives. Theoretically, at least, there would be no limit to the number of really good wood preservatives that might be offered to the consumer by competent treaters; but it is almost economically impossible for the trade to use more than a relatively small number of oil-type and salt-type preservatives. Practical limits are set by treating plant and material costs, preservative handling problems, customer specifications and procurement procedures.

Various Ways of Reporting Evaluation Tests

Since the emphasis in this paper is intended to be directed almost entirely toward the problems of preserving wood against wood-destroying fungi, no attempt will be made to interpret the evaluation of preservatives for insect or marine borer control. Insect damage to wood and furniture in houses in England and in Europe (14–2) is much more serious than it is in the United States and Canada, and the control measures are naturally that much more significant. The best current references are the recent volumes of the Record of the British Wood Preserving Association. Entomologists of the United States Department of Agriculture are continually experimenting with the use of soil poisons against termites at Saucier, Miss., for example. The periodic reports on the International Termite Exposure Test (12) contain the condensed results of observations on decay as well as termite attack. European test results can be approached through such summaries as that presented by Becker (14–3) for the Berlin–Dahlem testing station, particularly with respect to laboratory tropicalization experiments.

MacLean's summary (17) is a sort of final report of the marine borer work with which he has been connected for so many years. Progress reports on phases of the United States Navy Marine Borer Project (15) are issued frequently (22). Becker and Schulze (14–4) have reviewed some of the more recent European laboratory tests on the control of marine borers. The broad modern investigations in this country are covered by reports issued by the William F. Clapp Laboratories at Duxbury, Mass., and by reports of the periodic Marine Borer Conferences.

The progress reports on stake tests and post tests issued by the Forest Products Laboratory (5, 6) are comparisons of the behavior in outdoor test plots of southern pine sapwood stakes and posts treated with different preservatives. No direct attempt is made to correlate the results of stake tests and post tests at Saucier, Miss., for example. The practical interpretation of the results of the two types of test and the rating of preservatives is largely left to the reader. These reports on the stake, post and termite exposure tests regularly include one or more precautionary or warning paragraphs, representing almost ceremonial policy, that stress the limitations on the use of the test data.

In Europe, where the development of salt preservatives has always been important, and where there is a strong present interest in new preservatives and new methods of treatment, the reporting of laboratory evaluation tests in text books is handled somewhat differently than it is in this country. For example, in the third, revised edition of "Holzkonservierung" by Mühlke-Troschel–Liese, 1950, (19) the "Grenzwerte", or "boundary values", are given for critical test fungi for very many of the preservatives for which European standard agar-block test data are available. This acceptance of laboratory block tests seems to reflect clearly the attitude of the investigators at the Berlin–Dahlem testing station (14). Van Grenou, Rischen and van den Berge (23) make use of the same type of agar-block test data throughout their "Wood Preservation During the Last 50 Years", Leiden, 1951. So does Martinez (20) in his "Conservacion de Maderas", Madrid, 1952. Differences in the viewpoint here and abroad are revealed by the fact that Hunt and Garratt (18) in their 1953 edition of "Wood Preservation" handle the European agar-block tests and the soil-block tests in relatively short discussions, submitting laboratory toxicity data from agar tests only in two summary tables (V & VI).

Duncan (10) defines a specific threshold or threshold retention in terms of pounds per cubic foot of wood, as the "amount of preservative material based on *initial retention in the wood,* that *will be effective* in preventing decay by a particular test fungus". What is meant is the amount of preservative materials

determined by soil-block tests of weathered treated blocks. The definition as given above includes the important concept of permanence, or preservative efficiency, in sufficient degree to be effective over some time period, in spite of loss by evaporation or leaching. The definition will apply in principle throughout the rest of this paper. It can readily be broadened to cover a general threshold retention effective against critical fungi under use conditions of normal to maximum hazard.

Rahmus (21) used charts for comparing and correlating the absolute inhibition values on *logarithmic ordinates* for salt type preservatives and creosote, employing results obtained by an agar toximetric method and by agar-block tests of pine and beech wood. The most comprehensive comparison of results by the European standard agar-block method for all types of preservatives is Table 7a in the article by Schulze, Theden and Starfinger (14–1). The authors show graphically, on *logarithmic abscissas*, the relative limiting values for different preservatives against different test fungi.

A very concise graphical comparison of the results obtained with oil-type preservatives by both a modified agar-block test and by the soil-block test is represented by Figure 2 in Duncan's recent paper (10). This figure is a masterpiece of condensation; and a careful study of it is recommended. The threshold values in terms of lb/cu ft are shown on *arithmetic* ordinate scales.

The writer has illustrated the correlation among the relative threshold values for creosotes (7, Fig. 35) from the results obtained by weathered soil-block tests, by small ¾ inch stake tests, and by tests of pole-diameter posts. The wood in all cases was southern pine sapwood. The threshold values are shown in a simplified chart on an *arithmetical abscissa* base line.

Comparison and Correlation in Tabular Form

To provide another means for comparing the results of laboratory and test plot evaluation procedures some representative data have been expressed both as percent concentration and as pounds per cubic foot in Table 1. The following assumptions were used in arriving at the figures for percentage concentration in wood:

Specific gravity of southern pine sapwood, green volume and oven-dry weight basis	0.50
Weight of 1 cubic foot of such wood, oven-dry in lbs.	31.20
Weight of an amount of water equal to 30 percent of this dry weight, in lbs.	9.36
Weight of 1 cubic foot of wood at 30 percent moisture, in lbs.	40.56

Wood, water and air space for such combinations can be calculated from MacLean's charts (18). The weight of the *treated cubic* foot of wood is assumed to be the combined weight of the wood, water and absorbed preservative, for example:

Wood	31.20 lbs.
Water	9.36 lbs.
Creosote	8.00 lbs.
	48.56 lbs.

Here the creosote amounts to 16.47 percent of the wood-water-creosote "mixture". This calculated percent would, of course, be lower for higher moisture contents and higher for lower moisture contents; for example, it would be 14.60 for 50 percent moisture and 18.23 for 15 percent moisture. The percent figures for the agar flask tests are converted into lb/cu ft *of wood*.

To facilitate interpretation of Table 1 it is suggested that it be read from the upper left hand corner in a diagonal direction toward the lower right hand corner. It is evident that there is no correlation—no reciprocal and interdependent relation—among the values for *Madison 517 (Polyporus tulipiferus)* and those for *Lentinus lepideus* (Notes 3, 6). It is interesting that while the thresholds for the weathered agar-blocks and for the weathered soil-blocks are essentially the same for *Lenzites trabea* (3.00 and 3.20 lb/cu ft respectively) the weathered soil-block results are roughly 1.5–2.0 times the weathered agar-block results for *Lentinus lepideus*. On the basis of the latest available information, this fungus, because of its high creosote tolerance, is the most critical test organism for creosote. The best apparent correlation is shown in the weathered soil-block tests using this organism, and in the estimated threshold values for test plot experiments with creosoted ¾ inch stakes and with pole diameter posts. The figures for the posts are calculated for the *outer one inch* of the treated wood. The discrepancies between the group of figures for *Madison 517* and for *Lentinus lepideus* are in the same order whether one makes comparisons on the basis of percent concentration in the medium or in pounds per cubic foot. One may compare the results by the different test procedures, but correlation with outdoor exposure exists in only one segment of the table, in the lower right hand corner.

Cooperative Creosote Tests—Interim Appraisal

Much interesting and useful information will be obtained from the comprehensive cooperative creosote tests (1, 3, 9) now under way. The scope of the tests has broadened since their inception; and individual cooperators are still conducting their own investigations, essentially on their own responsibility. This is a natural development. However, without detracting from the ultimate value of the tests, the fact remains that the experiments representing the various present phases of the cooperative test procedures have grown by accretion instead of developing beforehand as parts of a truly coordinated plan. This growth is most desirable from the writer's viewpoint, but the results may not turn out to

Table 1—CREOSOTE EVALUATION TESTS; THRESHOLD RETENTIONS IN PERCENT CONCENTRATION AND LB./CU. FT.

Tests and Test Fungi	Notes	Agar-Flask Immediate a[5]	Agar-Flask Immediate b[5]	Agar-Block[3] Conditioned a	Agar-Block[3] Conditioned b	Agar-Block[3] Weathered a	Agar-Block[3] Weathered b	Soil-Block[3] Conditioned a	Soil-Block[3] Conditioned b	Soil-Block[3] Weathered a	Soil-Block[3] Weathered b
Laboratory Tests											
Fresh Oils											
Madison 517	1	0.03	0.012	2.41	1.00	3.80	1.60	<1.22	<0.50	1.70	0.70
	1	0.30	0.12	-	-	-	-				
	1, 7	1.50	0.62								
Aerated Oils											
	1	0.20	0.081	-							
	1	3.00	1.26								
	1, 7	>5.00	>2.13								
Coniophora Cerebella	2			1.22	0.50	-	-	-	-	-	-
Lenzites Trabea Madison 617	3			2.17	0.90	6.89	3.00	2.41	1.00	7.31	3.20
Lentinus Lepideus	2			3.70	1.56						
Europe	2			5.81	2.50						
Madison 534	3			3.80	1.60	10.97	5.00	7.94	3.50	15.61	7.50
Madison 534	3			-	-	-	-	-	-	16.82	8.20
Madison 534	3, 6									19.82	9.40
Madison 534	3									22.54	11.80
Field Tests											
¾ Inch Stakes	4									18.16	9.00
	4									21.33	11.00
Pole-diameter Posts	4, 7									18.16	9.00

[1]See Literature Cited for notes 1 to 5: 1. Baechler, 2. Schultze, Theden and Starfinger (14-1), 3. Duncan (8 to 11), 4. Colley, 5. Lumsden.
[6]The creosote here is the same as that at 1,7 above.
[7]See note 6.
[a]a is percent concentration and b is lb/cu ft.

be entirely satisfactory for correlation in the sense of this paper.

The reader will be gracious enough to bear in mind that the following discussion of the cooperative creosote tests is based on six years additional observation and experience since the tests were started, plus the assumed advantage of hindsight. The remarks are intended as an interim appraisal.

A final judgment on the behavior of the different creosotes and of creosote-petroleum and creosote-coal tar solutions under the conditions of exposure in the *marine borer tests* will probably be possible within a comparatively short time.

As far as the *laboratory agar flask toximetric tests* are concerned, the results confirm the general opinion that creosotes are toxic to *Madison 517;* and new evidence is presented (1) to show that forceful aeration of the oils decreases their toxicity to this organism. The significance of the change in toxicity and the bearing of the test data on the practical use of the creosotes are elusive.

The blocks in the soil-block tests were treated to a series of retentions which were calculated to straddle the threshold retention for each oil. The thresholds for the weathered blocks varies considerably for the different oils (9) but for these thresholds all of the residual oils, left in the wood after weathering, appeared to have one common characteristic, namely about 2.00–2.50 lb/cu ft (7, Table XXXV and Fig. 34) of the fraction distilling below 355° C. Analysis of the data in Duncan's Table 2 (11) indicates a residual amount of about 2.30–2.50 lb/cu ft of the same fraction of the tested creosote in blocks weathered during the warm months. This finding tends to confirm the hypothesis presented in the previously cited table and figure. The over-all results of the weathered block tests of the cooperative creosotes show thresholds of 9.0 or more lb/cu ft against *Lentinus lepideus* for most of the oils. This is interpreted as a minimum for severe exposure conditions, in view of later findings (11) in blocks weathered for longer periods. In the writer's opinion the tests in the soil-block series are the only ones of the cooperative tests that have directly approached the answer as to how much creosote is necessary to prevent decay at ground contact points.

The overall inference seems to be that an actual treatment retention of at least 8–9 pounds per cubic foot is necessary to protect against *Lentinus lepideus*. This figure may be too low. If it is about right as a minimum for severe ground line contact conditions, then the 4 lb treatments in the ¾ inch stake tests are too far below the threshold to be significant for comparisons of the different creosotes, and the 8 lb treatments are just at or below the thresholds; and besides, the amount of creosote remaining in the stakes at the time they were installed is unknown. In other words, there is no means of knowing how evaporation losses varied in the different lots—four treatments with each oil—during the intervals between treatment and the time the stakes were set in the ground in the 3 test plots. Decay is progressing rapidly after 3 years exposure in the 4 lb stakes, and it is well under way in some of the stakes in the 8 lb groups.

The 2×4×18 inch stakes were treated to an average retention of about 8 pounds. This amount is too near the threshold. The creosote distribution was undoubtedly more favorable for protection than in the ¾ inch stakes. The percentage loss of oil by evaporation was presumably less than from the smaller stakes, but how much loss occurred is not known. A substantial proportion of the 8 lb stakes in the Saucier, Miss., plot are showing decay.

It would appear, therefore, that the results of the tests of the treated ¾ inch and 2×4 inch stakes will eventually yield data that can be interpreted in terms of average life for less than threshold retentions of the various creosotes—4 and 8 lbs for the smaller stakes and 8 lbs for the larger stakes —under the respective plot conditions. It may be possible to estimate thresholds for the ¾ inch stake tests by inference from previous experiments, or by graphing the results from the small stakes as suggested in an earlier paper (7) or by segregating and tabulating the results for the stakes with retentions above the 8 lb level. The same procedure probably cannot be applied as easily to the 8 lb 2×4 inch stakes because of the lack of lower or higher retention groups. The stake test results probably cannot be translated directly into an answer to the question "How much of each of the several creosotes is needed to prevent decay under severe exposure conditions?"

As for the round southern pine posts in the test, that had an average retention of about 6 lb/cu ft, all were rated 100 percent "serviceable" in Dec., 1952, after about 3½ years exposure. Retentions ran as high in some cases as 7.7 lbs and as low as 4.2 lbs by weight before and after treatment. Most of them, therefore, were treated to overall retentions well below threshold figures for severe exposure conditions. These last two statements require some elaboration. While there are no assay data showing original creosote concentration and distribution, many of these posts immediately after treatment probably had actual retentions of 7.0–9.0 lb cu ft in the outer inch, and 12.0–14.0 lb/cu ft in the outer one-quarter inch, based on extraction assay of similar retentions. Such concentrations are highly protective. As a matter of fact the actual sapwood retention in these "6 lb by weight" posts may have been essentially equivalent to the sapwood retention in many an "8 lb by gauge" commercial southern pine pole. One would expect some of the experimental posts to last a long time.

For those unfamiliar with the time element in evaluation tests of creosote for land exposure, other than actual use and service in a treated structure, the following approximations may serve for orientation:

1. Agar toximetric tests	Several	weeks
2. Agar block tests	6 to	months
3. Soil-block tests	6 to	months
4. ¾ inch stake tests	6 to	years
5. 2×4 inch stake tests	10 to	years
6. Posts	10 to	years
7. Poles in line	20 to	years

These time estimates should be kept in mind not only in interpreting the results of the cooperative creosote investigations, but also in projecting plans for a coordinated series of evaluation tests. It remains to be seen whether the test plot experiments with the creosotes in the cooperative tests will indicate tangible differences among them.

The Significance of Various Test Procedures

Of the two types of laboratory tests considered particularly here, the agar toximetric test and the soil-block test, it will be assumed that the former—whether conducted in a Petri dish or in a closed Erlenmeyer flask—is a means of measuring the toxicity of the preservative material by calibrating the effect of the poison on the growth of a given test organism, frequently *Madison 517*. It is a toximetric test only, and valuable as such; but the evidence of the possible correlation of the test results with retention requirements in wood, or with the laboratory or field behavior of treated wood, is lacking or confusing. More than 20 years ago Rabanus went so far (21) as to say that investigation by the agar method permitted sure judgment only on the question whether or not a given preservative was suitable for the protection of malt extract agar against the attack of the test fungus. The test may be given its rightful place as a research tool in the category of preliminary examinations before a trial, which that preferably should be done before a preservative evaluation test is started.

The soil-block test as it is now being run provides information on the permanency-toxicity characteristics of a preservative. There is a good deal of information available as to which test fungi should be employed. The species and strains used at Madison appear to be very satisfactory. However, there is still plenty of work for the biologist to do in relating definite organisms or particular fungus strains with decay of treated softwoods and hardwoods under varying climatic and use conditions. Eventually, it would appear to be desirable to reach a working agreement on standard test preservatives as well as standard test fungi.

In the agar-block test as well as in the soil-block test the conditions are, as Baechler pointed out for the former, very favorable for the fungus. The soil-block test is the more severe, and it is more critical and realistic for oily materials. The soil-block culture lacks the very readily available food supply for the fungus that is present in the agar medium; but the treated block is exposed under apparently most favorable moisture and air conditions for promoting infection, and unless the amount of preservatives in the wood is high enough to repel the fungus attack the test block will decay. One can admit freely that the test is a severe one.

One may also speak of the condition of a stake test exposure in plots in Mississippi, for example, or in Florida, or in the Canal Zone as severe—about as severe as one can find deliberately—and that is, in a general way, why the locations were chosen. The essentially constant humidity and temperature of the soil-block test are lacking in the test plot, but in their place are perhaps even more significant diurnal variations and seasonal changes in rainfall and ground water table. The chance of infection, of course, is variable not only with respect to climate and site and the presence or absence of active wood-destroying fungi, but also with the variability of the latter factor in different parts of the same test plot. For these reasons attempts are now being made to arrive at a better understanding of the test plot conditions in the major experimental plots in this country.

There is one highly important combination factor in the soil, climate, treated wood, and attacking fungus equation, namely the resultant of the conditions at or just below the level of ground line exposure. One might venture the opinion that it should be possible to reach an approximate agreement as to the most significant biological and other factors in the exposure conditions in the really critical ground line section of a pole in use. The important factors may differ if one is working with railroad ties, or with mine props and timbers, or with the above ground line section of a pole, or with the tops of piles that have been cut off square to receive the timbers supporting railway track or highway. But in any site where exposure conditions vary with the elements, the air, water and temperature conditions may be optimum at some season of the year as far as the growth of wood-destroying fungi are concerned. Regardless of concomitant variations, and aside from the fact that the optimum period may be relatively short or nearly continuous, if appropriate fungi are "available" and free to attack when this optimum period occurs the conditions will approach those of the soil-block test.

Efforts are now being made to standardize the method for stake tests (American Wood-Preservers' Association, Preservatives Committee P-6). Two sizes are proposed, namely (a) $\frac{3}{4} \times \frac{3}{4} \times 18$ inches, and (b) nominal $2 \times 4 \times 18$ inches. In the writer's opinion one of the most important parts of the proposed standard procedure is the section dealing with the handling of the specimens after treatment and up to the time they are installed in the test plot, particularly when one is planning tests on oil-type preservatives such as creosote or solutions of pentachlorophenol or copper naphthenate in an oil vehicle.

It is practically impossible to treat, store, ship and install any substantial number of small stakes in a comparable series of tests of such preservatives without running into complications of varying time periods, and variable evaporation losses between treatment and installation. It would therefore appear to be essential to hold each batch in any given series treated with oil-type preservatives until evaporation and other losses slow down or reach the gradual rate of an almost asymptotic curve. Such a practice would bring the oil preservatives to a state approaching equilibrium and would iron out some of the retention variables that otherwise may influence the results in test plot experiments. In the writer's opinion the application of a weathering cycle to a sizeable proportion of all treated stakes would not only facilitate correlation with the soil-block tests but also improve the basic acceleration characteristics of the tests and speed them up, with a consequent reduction in time periods.

It goes without saying that an important part of the permanency phase of the soil-block test is the weathering cycle employed, during which volatile preservative material may be lost by evaporation or displacement and water soluble material may be lost by leaching. Eventually an acceptable indoor weathering technique may be developed for blocks, but none of the present exploratory investigations of such laboratory procedures appears to be applicable practically to stakes. For the time being, therefore, one would probably have to plan for outdoor weathering of all specimens, i.e.; exposure, as in the Madison soil-block technique, to the local climatic conditions. Duncan (11, Tab. 2) has recently shown the effect of varying outdoor weathering periods on creosoted blocks. The effect of a 60 day late spring and summer outdoor exposure of the treated blocks at Madison seems to approach the effect of exposure at Gulfport, Miss., for example, of 5–7 years for ¾ inch stakes, and 15–20 years for pole-diameter posts.

A substantial part of the creosote absorbed by the test blocks at treatment is apparently lost in a relatively short time. In specimens treated with toluene-creosote solutions about 88–90 percent of the calculated creosote losses over a four month late Summer and Fall period took place in the first 30 days. For the 21 percent residue creosote used in the experiments summarized in the cited Table 2 (11) the data indicate that at about the 8.0 pound level a loss of 47–54 percent of the whole oil is correlated with a calculated loss of 60–68 percent of the fraction distilling below 355°C. Such losses occurred in an outdoor weathering period of 45–60 days in late Spring and Summer months. The results of this latest published series of experiments appear to be in line with those obtained in the same laboratory and published previously for creosotes of about the same residue and specific gravity. A 90 day weathering period beginning about June first would probably be about right for ¾ inch stakes. A somewhat longer period might be better for 2×4 stakes. In both cases care would have to be taken to insure free exposure to air movement and rainfall (or spray) under alternating day and night conditions.

One might plan to obtain a laboratory answer or plausible inferences from weathered blocks, and then test laboratory results with ¾ inch weathered stakes. For such an experiment in correlation it might be advisable to cut the blocks and the stakes from the same blanks. It would appear to be entirely possible for a relatively small test to cut groups of a number of ¾ inch blocks and a ¾ inch stake from the same or very nearly the same annual rings. A preselection

of logs, a satisfactory system of sawing, preferably approaching the quarter-sawing principle, and subsequent sorting of the boards would be essential. It is a rather expensive procedure, it calls for happy and understanding cooperation between biologist and wood-worker, but it can be done, and the writer knows of no better way to get as truly matched specimens. It is more easily accomplished at the Forest Products Laboratory for instance, than in less well equipped and experienced places; but again, it can be done, even if the logs are handled at one point and the planing and cutting up of the boards at another. For large scale tests such refined matching is impractical.

When there is sufficient continuity in policy and management to permit planning for long range experiments it would also appear to be desirable to apply a weathering cycle to the round test posts in any full scale evaluation program. For example, assume a reasonable number of southern pine sapwood posts, 6 feet long and about 4 inches in average diameter, treated in a satisfactory series of gradient retention groups varying from below to above the expected threshold. One could divide each group into 2 lots, one (a) to be shipped and installed as soon as practicable after treatment and the other (b) to be weathered before installation. There might be at least 10 posts in each of the (a) lots and at least 20 in each of the (b) lots. The latter could be stacked X-wise, just as fresh cut lumber is frequently stacked in the South, but over an iron pipe or a treated rail, with the lower butt ends resting on concrete or treated timber supports above the "flood" level of heavy rains. The length of the weathering period could be governed by periodic assay of control specimens. A period of 120 days, say during June, July, August, and September would probably be long enough to permit the evaporation from such small posts of a substantial proportion of low boiling ends of creosotes or of petroleum carriers.

Correlated Evaluation Tests

If all of the above tests are being applied to preservatives already in use it should be feasible to employ true samples of the commercial treating solutions throughout, and at the same time arrange for the treatment of a substantial number of full size commercial units for a documented service test. Securing such treated units is more difficult and may be practically impossible in the case of new preservatives, either because of supply difficulties or because commercial equipment cannot be spared or converted for a large scale commercial experiment.

Logically, the service test should come after the evaluation tests anyway, but things do not always work out that way. In any event, a sufficiently large and representative sample of the commercially treated units that go into a service test should be branded properly and characterized completely as to timber species, time of cutting, seasoning, size, manufacture, sapwood depth, sap and heart volume, preservative, time and place of treatment, retention by gage or weight and by chemical assay to determine preservative concentration and distribution in the wood, time interval between treatment and installation, and dates of installation. To be most rewarding, enough units should be treated and characterized for distribution and installation under significantly different climatic and site conditions, all of which should be carefully described and recorded. Location and labelling of the treated units could well be mapped. The making of the records must really be done for posterity. Such a service test is not easy to set up. There are not many in this country that conform completely.

The writer has become convinced that one should never purposely change the below ground and ground line environment of a test specimen by pulling it out of the ground periodically for inspection. This cuts straight across currently accepted practice for everything from ¾ inch stakes to pole-diameter posts; but it is suggested that the practice needs reexamination. Once a treated specimen has been properly installed the preservative may be assumed to have some effect—to a greater or lesser degree—on the biologic population of the soil in contact with the specimen. Conceivably this effect might be stimulation by very minute quantities of preservative poison, but generally one would look for and hope for a degree of inhibition. When freshly treated units are installed in actual service, such as poles or ties for example, there may actually be a poisoning of the adjacent soil, particularly at or just below the ground line. Normally the ground line of a pole is not changed much after installation except by error or accident, and the relation of soil and below ground pole surface remains practically constant, generally speaking, throughout the service life of the pole.

Lifting out stake and small post specimens, and loosening and jacking up larger post specimens (16), and partially or all around excavation of poles in line obviously disturb the soil-wood environment. Vigorous loosening of stakes and posts should be avoided. Jacking out posts is a better procedure than digging out the soil around the ground line. There is at least the possibility that a lifting out inspection practice accelerates the acceleration for which the test was planned. The variables introduced probably have a relatively greater effect on specimens treated to below or to closely approximate threshold retentions; because adequately treated specimens seem to remain sound year after year, regardless of the examiner's technique.

Two things can be done about all this. Enough specimens could be treated so that an adequate pilot lot could be inspected by lifting out as at present, and as often as desirable. This lot would provide an index of the incidence of decay and the probable general conditions of the specimens in the larger lot. The latter should remain undisturbed as long as practicable. In the writer's opinion this principle should apply to all test plot experiments, regardless of the size of the test specimens; and as far as poles in line are concerned the digging necessary to permit inspection should be kept at a minimum.

To carry out the idea expressed above successfully for small specimens one might have to make some change in the length of ¾ and 2×4 inch stakes. Under certain temperate site conditions these specimens, when set 7–9 inches only into the ground, tend to heave or work out of the ground in the course of the alternating summer and winter seasons. This means change of the ground line level, possibly more rapid loss of volatile preservatives, some looseness and air space, and very probably some elements of increased acceleration of the tests. Such acceleration is bound to be irregular and variable, and its effect is difficult to appreciate. Usually, under careful supervision some attempt is made to reset the specimens periodically by tapping or hammering them back to their original ground line level, and by tamping the soil around them. However, this procedure is followed on a somewhat irregular schedule, its thoroughness depends both on the operator and the condition of the ground, and the results are uncertain. One way out of the difficulties would be to make the stakes 24–30 inches long for the experimental lots that are to remain undisturbed, and to set the stakes firmly 18–24 inches deep– depending on soil and climate—so that they would have a better chance of staying put and a better relation to periodic changes in water table. Final inspection of decaying representatives of such stakes would coincide with

the time when they could be broken off with a relatively light spring balance load, or with a slight pull by a practiced hand.

Perhaps it may not be necessary to use both the ¾ inch stakes and the 2× stakes in accelerated test plot tests. Neither of course, is in the shape of treated wood units that are normally used commercially, with the possible exception of some sawed fence posts, grape stakes or hop poles. The 2× ×18 inch sapwood stick has gained a certain academic sanctity because it has been used. Its size may be some advantage in termite exposure tests. It is tangible and not easily lost. However, the writer is strongly inclined toward the ¾ inch unit, because of its relative cross sectional shape, compared to the block size, and because it can be made from selected thin sapwoods, such as Douglas fir, lodgepole pine, jack pine and western cedar. These species should be included sometime soon in evaluation tests of volatile or partly volatile preservatives.

It is the writer's belief that the test plot exposure of creosoted specimens treated to 4 and 8 pound retentions, or to 6 pounds only or 8 pounds only, is not a truly accelerated test, except for the effect of site and biologic enemy population on the life of the given specimens. Preferably all the specimen lots should include a gradient series of retentions that run from below to above a protective threshold and the principle should apply to all preservatives and all types of specimens tested. The decay of specimens having less than threshold retentions provides visible and certain evidence of insufficient preservative. This is almost if not quite as important in judging the actual threshold retention level as the complete protection afforded by the adequately treated, higher retention specimens. Satisfactory comparison and interpretation is difficult or impossible when one is dealing with variable degrees of decay in all of the specimens in groups treated to below threshold retentions. Acceleration over the whole retention gradient for all specimens can be promoted by weathering, as suggested in the experimental plan described in the following paragraphs.

One must, of course, continue to attempt to evaluate the tests now in progress. If one were making a new start the following schedule of correlated tests is suggested as having economic and time advantages that seem worthy of careful consideration. It is assumed that all preliminary tests, such as agar toximetric tests, metal corrosion tests, etc. have been run, and that questions of toxicity to animals or humans, and problems of cost and availability have been reasonably resolved up to the point of warranting a thorough evaluation.

The complete correlated series of tests would include 1) soil-block tests, 2) ¾ inch stake tests and 3) round post tests, all specimens to be of southern pine sapwood; and if general considerations justified the risk and expense one could add 4) treatment and installation of commercial units. In order to avoid molding or blue-staining of the sapwood or possible decay, the logs for the boards to be made into blocks and ¾ inch stakes, and the posts should be cut in late Fall or early Winter. The suggested general scheme of test for oil-type preservatives involves a planned schedule for:

a. **Manufacture** of the boards, blocks and stakes, and also of the peeled posts, in late Fall or early Winter.

b. **Conditioning** the blocks and stakes to approximately the same moisture content, and conditioning the posts as nearly as practicable to the same moisture content as the blocks and stakes. It is assumed the boards would be carefully kiln dried before manufacture into blocks and stakes. The posts might be conditioned by partial kiln-drying followed by a period of storage in a heated basement.

c. **Treatment** of all experimental units within the shortest practicable period, say starting in April and finishing by May 31.

d. **Weathering outdoors** in any given locality of all treated units under the same general climatic conditions for appropriate periods beginning about June 1 and running to about September 30.

e. **Starting block tests and installation of stakes** and posts in the period from September 1 to October 31.

f. If practical, **commercial treatment of service test units** preferably in May, open pile storage June to September and installation in late September or October.

g. Adequate provision for **chemical assay** of representative experimental units from block, stake and post groups to determine variation in retention, and the amount and character of preservative losses during the course of the respective exposure tests.

The timing schedule shown above and below is believed to be rational and illustrative of a workable plan; but it is not, of course, to be taken as inflexible.

In broad detail the experimental lots would be fitted into a pattern like the following:

1. **Soil-Block Tests**

Gradient retentions, using toluene diluent, from below to above expected threshold.

Group a. For exploratory tests of freshly treated blocks, conditioned about three weeks, to determine approximate effectiveness of preservative before weathering.

Group b. Weathered **60 days** say during June 1—July 31; reconditioned, and placed in culture test about September 1.

2. **¾ Inch Stake Tests**

Same gradient retentions, with and without toluene diluent, as for soil-blocks, from below to above expected threshold.

Group a1. Representative samples from each retention lot of toluene dilute specimens, 30 inches long, for exploratory tests of freshly treated stakes, each retention group to be close-bundled and wrapped in aluminum foil, as soon as practicable after weighing for retention and evaporation of toluene, and kept wrapped until installation at earliest practicable date.

Group a2. Ditto, for representative samples treated without use of toluene diluent.

Group b1. Toluene dilute treatment specimens for all retentions, 30 inches long, weathered **90 days** during June 1—August 30, representative samples to be assayed for preservative retention immediately after treatment and after weathering. Each retention group to be approximately bundled in aluminum foil at the end of the weathering period and to be kept that way until installation in September or early October.

Group b2. Ditto for specimens treated without the use of toluene diluent.

Group c1 and c2. Treated controls for each retention group and for the toluene dilute and straight preservative treatments respectively, 18 inches long, for periodic lifting out inspection, preservative assay, and isolation of primary decay fungi; weathered **90 days** as for groups b1, and b2, and properly segregated and wrapped by retention groups in aluminum foil. Installation with groups b1, and b2 in September or October. (The same procedures could, of course, be followed for the 2x4 stakes if apparent advantages warranted the additional work and cost.)

3. **Round Post Tests**

Six foot carefully peeled or machine-shaved southern pine posts, mostly sapwood, 3–5 inches in midpoint diameter, and averaging about 4 inches; commercial type empty cell treatments at 5 gradient retentions, 2 below and 2 above the expected threshold, with somewhat broader intervals than those used in the block and stake retention gradients; not less than 30 and preferably at least 50 posts in each retention lot, plus appropriate sample posts for assay of penetration, preservative retention and distribution. (As far as practicable the selected posts should show medium growth rates, say not under 4 or over 10 rings per inch in the outer 1½ inches of cross section.)

Group a. Ten posts from each retention lot, representative of retention spread, to be shipped and installed as soon as practicable after treatment.

Group b. Twenty to forty posts from each retention group to be weathered under same conditions as for the ¾ inch stakes for 120 days from about June 1 to September 30; sample posts to be assayed for preservative retention and distribution immediately after treatment and after weathering; installation between October 1 and 31. (The tops of these posts should yield significant indication of the effectiveness of the preservative and above ground exposure conditions.)

4. **Service Tests of Commercial Units**

To be worked out when practicable by consumer and supplier, preferably so that the units can be treated, then held in open pile storage for at least 90 days; installation preferably in late September or early October.

Biologist, Chemist and Engineer

Important questions that must be settled before such a series of evaluation tests is undertaken have to do with location and size of the test plot or plots and the plans for truly random distribution of the test units within each plot. As to location, the major conditions for exposure would be met if one plot were established in sandy loam soil in a warm, moist climate, as on an appropriate line between Houston, Texas and Jacksonville, Fla., and the other in good agricultural land in a mild temperate climate not much farther north than a line between St. Louis, Mo., and Richmond, Va. The rate of decay in colder temperate climates or in dry areas appears to be too slow or too erratic for satisfactory accelerated tests.

All plots should be large enough for continuity of operation and proper spacing of specimens. Representative weathered samples from any given series of gradient retentions should be installed in each plot. For small stakes there appears to be no completely adequate substitute for a Latin square arrangement that will satisfy classical statistical requirements; but strict conformance, unless one has plenty of space in which to work, may be difficult. For weathered stakes as defined above, some rational method of fair distribution of specimens from any given treatment group to say 10 different areas within the plot may be more practicable both as to arrangement and as to reliability of results. Each of the 10 areas should contain representative samples of the whole retention gradient for any given preservative. One might as well consider the same scheme for posts also, although with their much longer expected life in the plot the arrangement may not be as important as for small specimens.

Discussion of soil characteristics, fungus flora, the mutual antagonism of soil organisms, and other factors make another story, too long to be told here. Still another story which also must be omitted would deal with preservative requirements, risk of infection and interpretation of results for above ground outdoor exposure (24) of untreated and treated wood. The same holds for the unique exposure conditions that pertain to railroad ties in track, in different ballast and in different climatic environments. Each type of end-use situation seems to require restudy and better clarification, with particular reference to biologic enemy factors.

By training and experience, the writer has been strongly inclined to the belief that the mode of thought in any broad evaluation program should be predominantly biological. However, it will be evident from the preceding paragraphs that the biologist will need sympathetic understanding and the full cooperation of the chemist and the engineer. One of the most interesting and perhaps most significant results shown in Duncan's illustration of comparative agar-block and soil-block thresholds (10, Fig. 2) is the relative shift of the resistance of *Lentinus lepideus* and *Lenzites trabea* when wood is treated with straight creosote, straight 5 percent pentapetroleum, and a 50/50 by volume blend of the two. The shift is more clearly shown in the results of the soil-block tests because of the wider spread in the thresholds. Attention is directed to the levels indicated for the two fungi, respectively shown by the position of the numbers 1 and 2. No. 1, *Lentinus lepideus,* is at the highest threshold for creosote (Fig. 2, A) and the lowest for 5 percent penta-petroleum (Fig. 2. B); and for the latter as well as for the blend (Fig. 2, E) the most resistant test fungus is *Lenzites trabea.* This shift is clearly indicated in a previous paper (8). Furthermore, in the soil-block tests, the blend is more effective overall than either of the two basic preservatives used alone. This is a biological fact of tremendous importance in planning evaluation tests.

It is essential to recognize, with a view to insuring a separation of function, the difference between performance of a laboratory operation such as the soil-block test, and the work of fundamental research and development that may be directed toward change or improvement in the test procedure or in its interpretation. Studies of the latter type are continuing, particularly on soil problems, on the weathering techniques and on the use of solvent vehicles in oil-type preservative treatments. However, the basic methodology of the soil-block test has been fairly well established (7, 10, 11). Figuratively speaking, the road has been laid out and traveled; and goods are moving over it in fairly satisfactory manner. From a biologist's viewpoint, still in a figurative sense, the question might be asked, "How can the road be kept open and the goods be kept moving, and at the same time be sure that the exploration of new routes—perhaps better in both location and grade—is not discouraged or prevented by expediency?"

It is not intended to suggest that the two functions be separated by solid walls of non-communication, but the concepts of the two functions should be discrete. The application of the soil-block test procedure can be reduced to a fairly well controlled system that seems to be basic for an evaluation program. If desirable, a series of soil-block tests can be repeated in a relatively short time to correct errors or to confirm conclusions. Such a process is more like production or transportation of goods than it is like exploration or design or inquiring experiment. The latter, by nature, has no very well defined end point. It may eventually result in an improved product, but it should not be allowed to block the reasonably satisfactory production line or the road over which the goods are appear-

ently being successfully transported. Exploration and experiment must be sponsored and encouraged, but in the meantime, one should make the best possible use of the trail that has been marked out until the new road is shown to be better.

Soil-block tests of outdoor weathered units have yielded results—for the first time for any laboratory test—that apparently establish necessary treatment retention levels for creosote to insure a satisfactory degree of preservative permanence and a reasonable expectancy of long service life for treated wood. The tests reconfirm the solid reputation of true coal tar creosote when properly used in sufficient quantity. The tests also yield important hints for improving preservative effectiveness. On the basis of the soil-block tests a general plan for coordinated series of preservative evaluation tests has been suggested, with a view to developing test data that can be truly correlated. Until repeated series of such coordinated tests are run, one can only say that the possibilities of correlation between laboratory results and field experience have not been fairly explored.

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The Exudation of Oil Type Preservatives From Treated Wood

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Thirty-five factors affecting exudation of oil-type preservatives are listed and discussed. In each case possible method for reducing exudation is given.

AFTER WOOD IS TREATED with an oil-type preservative, varying percentages of the preservative may come to the surface. If the volatility or distillation range of the oil is such that a residue remains on the surface the term "bleeding" is generally applied. If the preservative is a crystal-type dissolved in a petroleum carrier of such high volatility that none of it remains on the surface of the wood after exudation, and only the crystals are deposited, the term "blooming" is generally applied.

Prior to the early twenties practically all full length pressure creosoted poles were treated by the full cell process, using 12 lbs. of creosote. These poles were used principally in the south. As their use spread north, the purchasers objected to the bleeding, being accustomed to the use of poles with butt treatment only. To extend their market the treating plants began to study methods for the control of bleeding. Excellent progress was made through the combined efforts of treating plants and users. A great deal of credit is due to those who contributed to this progress. The present day creosoted poles are remarkably clean.

Bleeding is objectionable to many users of poles, while other pole users and users of railroad ties in general favor bleeding with the belief that the resultant coating adds to the service life of the treated wood by holding the preservative in the wood and by the prevention of checking and top shattering. Coatings are actually being applied on cross-ties, timbers and pole tops to prevent checking and other weathering effects.

Many users of poles and other treated material are more interested in long life than they are in cleanliness of surface and do not wish to make any possible sacrifices in life to obtain slightly cleaner surfaces. Actually the possible extra expense that may be occassioned by some difficulties with bleeding could be inconsequential compared to the possible cost of early replacements caused by reduced service life.

Blooming has no apparent benefit, as it simply shows a loss of preservative. Very little is known about blooming either as to its extent or to the type of carriers which must be used to prevent it. Where a very light carrier such as Stoddard Solvent is used, it is customary to add an anti-blooming agent, but no data have been published showing whether or not anti-blooming agents are needed with somewhat higher boiling solvents such as No. 2 Fuel Oil.

The general cause of the exudation is that there is a high concentration of preservative near the outside of the treated piece. Even in the case of thick sapwood southern pine poles treated to an 8 lb. retention, there may be 16 lbs. per cubic foot of preservative in the outer one-eighth inch. This preservative near the outside is brought to the surface by many different forces. Natural gravity flow in a vertical piece would be down and out. The entrance of moisture in wood causes some expansion and also, since water tends to displace oil in wood, variations in moisture content might cause some exudation. Water in wood expands on freezing and might force oil to the surface. Movement of air in and out of the timber would probably cause exudation. On a cool night, air in the timber would contract and draw in additional air. During the heat of the day the air would expand and tend to force out some of the preservative near the surface. As wood is heated it expands and this pressure might force some oil to the surface. All of the above factors would be greater on the side of the piece where the temperature would be higher and the oil less viscous due to heat of the sun.

If the process of treatment could be conducted so that there would not be a high concentration of preservative near the surface, exudation would be greatly reduced. It has been stated that exudation could not be produced in an 8 lb. Southern Pine pole section after ¼" had been shaved from the outside surface. Final vaccum, final steaming, expansion bath, boiling under final vacuum, solvent-cleaning, additives, hot water baths and a combination of some of these have all been reported to reduce exudation. If such treatments result in a reduction of retention to less than specified, there will be an attendant reduction in service life. If, however, the retention is according to the specifications and the highest concentration of preservative is only removed to a point inside the wood, the service life might actually be increased due to a reduction in the loss from the wood, caused by a high concentration at the surface.

While the exact nature of the movement of oily materials in wood is not known, there is evidence to show that it moves both as a liquid and as a vapor, depending upon volatility, viscosity and other factors. A fluid material would have more tendency to flow out or be forced out. A low boiling material would move out faster by vaporization than a higher boiling one. Where the boiling range is sufficiently high, only the lower boiling fractions would move out except over very long periods of time. When a higher boiling material does move to the surface of the wood as a liquid, there is more residual material to remain on the surface after the lighter fractions have evaporated away.

Some factors which affect the exudation of oil-type preservatives from wood are listed below with a brief discussion and suggested possible methods for control. Adequate information is lacking on many of the factors mentioned and considerable difference of opinion may exist on the relations between conditions and exudation effects, as well as possible means for reducing exudation. As previously mentioned, much more exact information is required before a solution to the problem can be definitely outlined.

Factor 1: Species of Timber.

Discussion: Generally species of timber with thin sapwood exude

more. Species difficult to penetrate exude more than those easily penetrated.

Possible Method for Reduction of Exudation: Lower retentions where bleeding is a factor. Don't ship some species to areas where bleeding is a particular problem. See paragraphs which follow. Additional research needed.

Factor 2: Nature of Timber.

Discussion: Resinous and thin sapwood pieces exude more. Type of growth has some effect.

Possible Method for Reduction of Exudation: No practical control.

Factor 3: Machine Trimming.

Discussion: Machine trimmed poles exude less than those not machined. Areas on trimmed poles not reached by knives exude more. The improved surface condition effected by machine trimming may be due to removal of resin formed on the surface when the bark is removed, difference in cell content in the exposed outer layer, or opened cells on the trimmed surfaces.

Possible Method for Reduction of Exudation: Machine trim all poles to be shipped where bleeding is a factor.

Factor 4: Mold and Stain.

Discussion: Recent work has shown that the development of some mold and stain organisms in wood may greatly affect penetration and retention. When dry the molded wood is easily penetrable and retains much greater quantities of preservative. During heavy rains the molded wood soaks up great quantities of water which might seriously reduce penetration and retention. Thus the presence or absence of mold and stain may affect uniformity of treatment and consequently the occurrence of exudation.

Possible Method for Reduction of Exudation: Treat poles before molding occurs. Condition in such manner that molding organisms do not develop. Apply antimolding chemicals soon after cutting. Infect and control molding and staining so that it is uniform. Much information needs to be developed on this recently evaluated factor.

Factor 5: Degree of seasoning.

Discussion: Green timber exudes less than seasoned possibly due to less retention near surface. When green and dry pieces are treated together the dry pieces retain more preservative.

Possible Method for Reduction of Exudation: Allow plants more time to fill orders so that better selection can be made and best treatment conducted for the degrees of seasoning. *Select pieces with same degree of seasoning or condition to make all equal.*

Factor 6: Time of the year when treated.

Discussion: Generally poles exude less in cold weather, except as exudation may result from freezing of water in the poles.

Possible Method for Reduction of Exudation: No control.

Factor 7: Uniformity in moisture content of timber when treated.

Discussion: If green and dry material are mixed in a charge, the dry material will absorb more presevative and exude more, even though given initial steam which tends to equalize the moisture conent.

Possible Method for Reduction of Exudation: Make up charges of uniformly seasoned material or use treating process which will equalize them.

Factor 8: Use of initial steam.

Discussion: Initial steaming raises the temperature of the wood and reduces exudation due to reduction of viscosity of the oil, with consequent increased penetration and increased penetration and increased removal of oil from the outer rings of the wood.

Possible Method for Reduction of Exudation: Use initial steam even on dry stock where cleanliness is a factor and the wood is not injured by steam. The duration should be from 1 to 3 hours on dry material.

Factor 9: Length of initial steam period.

Discussion: If the initial steaming period used with green stock is insufficient, a mixture of creosote and water may exude from the treated wood. Longer steam periods increase the surface temperature and reduce the viscosity of the preservative, causing it to flow from the outer rings of wood during final vacuum.

Possible Method for Reduction of Exudation: Use sufficient steam periods for proper conditioning.

Factor 10: Length of vacuum period after steam.

Discussion: Insufficient vacuum leaves excess water near surface which tends to cause exudation.

Possible Method for Reduction of Exudation: Use quick, high vacuum of sufficient duration based on size.

Factor 11: Treating process used.

Discussion: Empty cell processes generally exude less than full cell due to less concentration of oil near the surface and generally deeper penetration.

Possible Method for Reduction of Exudation: Use empty cell when cleanliness is desired and retentions allow use, unless experimentation shows that the species being treated tends to hold air so that it escapes after treatment to cause bleeding.

Factor 12: Pressure of air used in treatment.

Discussion: Generally the higher the air pressure used in treatment (up to a point) the less the bleeding. The higher pressure blows more oil from near the surface. This may not be true with some thin sapwood species.

Possible Method for Reduction of Exudation: Use the highest practicable pressure. For example, with treatment of 8 lbs. per cu. ft. the air pressure may be up to 90 lbs. with small southern pine poles and up to 60 lbs. with fir. The many variables involved require testing to determine the optimum air pressure to use.

Factor 13: Temperature of preservative during treatment.

Discussion: Higher temperatures reduce exudation.

Possible Method for Reduction of Exudation: Have a minimum of 200°F. in cylinder by end of pressure period.

Factor 14: Blowing back.

Discussion: When air pressure is used to blow the oil out of the cylinder after treatment, it may force some oil back in the wood near the surface; if it exceeds the point to which the pressure has fallen. This surface oil flows out easily.

Possible Method for Reduction of Exudation: After the pressure is released it should not be allowed to go below the air pressure applied for blowing back. It is desirable to pump back with thin sapwood species.

Factor 15: Duration and intensity of final vacuum used.

Discussion: Higher and longer vacuum periods aid in the production of cleaner material.

Possible Method for Reduction of Exudation: Use at least 1 hour final vacuum up to 24" in 30 minutes.

Factor 16. Final steaming.

Discussion: Final steaming (1) raises the surface temperature of the wood (2) lowers viscosity of the preservative causing it to blow out more readily (3) expands the air in the wood so that more oil is blown out and (4) causes more suction of air back into the pole after coming in contact with atmospheric conditions; all of which has a tendency to reduce exudation.

Possible Method for Reduction of Exudation: Where extra cleanliness is desired use final steam, up in 1 hr. and held at 240°F. for 1 to 3 hrs. on southern pine and 2 to 3 hrs. one thin sapwood species. Overinjection. sufficient oil to take care of amount removed during final steam period.

Factor 17: Expansion bath.

Discussion: Same effects as steam noted above though somewhat less due to lower temperature used.

Possible Method for Reduction of Exudation: Use up to 3 hrs. total at 220°F. More commonly used on woods other than Southern pine. Of doubtful value on some species.

Factor 18: Boiling under final vacuum.

Discussion: Similar effects to Nos. 16 and 17. Possibly more oil removed from surface.

Possible Method for Reduction of Exudation: Use about 3 hrs. at about 200°F.

Factor 19: Depth of Penetration.

Discussion: In general, with a given species and impregnation, there is more exudation in material with less penetration.

Possible Method for Reduction of Exudation: Entire treating procedure should be aimed at obtaining deepest possible penetration.

Factor 20: Distribution of preservative in wood.

Discussion: The usual treating processes give a heavy concentration of preservative near the outside which tends to move to the surface.

Possible Method for Reduction of Exudation: More information is needed on methods to move the point of highest concentration to a position just far enough inside the wood to prevent exudation.

Factor 21. Amount of retention.

Discussion: Greater retentions cause more exudation, other factors being equal.

Possible Method for Reduction of Exudation: As retentions are based on service conditions, the proper amount of oil must be retained; however, more oil than is necessary should not be used where cleanliness is a factor. Where service is severe and cleanliness is also desirable, use extra steps in treatment so that bleeding with higher retentions will be minimized.

Factor 22: Retreatment.

Discussion: Retreatment for insufficient penetration or retention results in more exudation due to more preservative near the surface.

Possible Method for Reduction of Exudation: Use ample conditioning periods and suitable treatment conditions in accordance with size and condition so that necessity for retreatment is reduced.

Factor 23: Amount of high boiling material in preservative.

Discussion: The greater the amount of high boiling material, the more tendency toward bleeding or more explicitly the more tendency for the material which exudes to remain on the surface after the lighter fractions have evaporated.

Possible Method for Reduction of Exudation: Where cleanliness is the important factor, place a maximum limit of about 30% on the distillation residue above 355°C.

Factor 24: Nature of high boiling material in preservative.

Discussion: High boiling residual, either from coal tar (pitch) or petroleum (asphalt) tends to cause bleeding when in preservative. If the preservative is entirely a distillate, the tendency toward bleeding is not nearly so marked.

Possible Method for Reduction of Exudation: Where cleanliness is a factor, use distillates and do not allow inter-mixing in plant.

Factor 25: Viscosity of the preservative.

Discussion: Taken alone, this may or may not be a factor in bleeding. More bleeding is noticed with more viscous oils; however, these are also higher residue oils so that the amount and type of residue may be the important factors rather than the viscosity.

Possible Method for Reduction of Exudation: Use higher treating temperatures with more viscous oils.

Factor 26: Amount of insoluble in preservative.

Discussion: When true insolubles (dirt, carbon, etc.) are high they may deposit in appreciable depth on the surface of wood, tending to induce bleeding.

Possible Method for Reduction of Exudation: Present AWPA specs. are well on the safe side in preventing this type of bleeding. Insoluble may be reduced by bringing water content to about 0.5% and allowing to stand in tank.

Factor 27: Amount of water emulsion in preservative.

Discussion: Emulsion in preservative tends to filter out on the surface of wood, leaving a deposit.

Possible Method for Reduction of Exudation: Hold a water content of not over 2% in preservative where cleanliness is a factor.

Factor 28: Amount of sludge in preservative.

Discussion: Some oil preservative solutions form true sludge reaction products due to lack of mutual solubility and through use. This insoluble material tends to filter out on the surface and cause bleeding

Possible Method for Reduction of Exudation: Hold under a maximum amount of sludge as determined by the hot centrifuge or other suitable method.

Factor 29: Intermixing of preservatives in treating plant.

Discussion: Where a plant treats with solutions containing tar or heavy petroleum, intermixing in the cylinders and lines may cause other preservatives to pick up enough pitch and asphalt to affect bleeding appreciably.

Possible Method for Reduction of Exudation: Keep preservatives from intermixing by using separate lines and pumps. Systems that will drain completely help to prevent intermixing. Keep the cylinder clean.

Factor 30: Antiblooming Agents.

Discussion: Few data have been published on the effect of antiblooming or plasticizing agents in wood preserving solutions. They are added to prevent dissolved toxic compounds from blooming out of wood with consequent loss. The exact nature of the action is not known. It is customary to add antiblooming agents to the preservative solutions used in dipping sash and millwork which are made up with light petroleum distillates but they are not being used with some of the comparatively light oils used for the treatment of poles and lumber. It has been shown that a petroleum solvent with a distillation residue of 90% above 355°C will prevent loss by blooming but data are lacking on the need for antiblooming agents in oils boiling between this one and Stoddard Solvent.

Possible Method for Reduction of Exudation: Use antiblooming agents in solutions with dissolved crystal preservatives unless it is known that the petroleum solvent used will prevent loss of preservative due to blooming.

Factor 31: Sunlight.

Discussion: Direct sunlight greatly increases the surface temperature of poles, lowering the viscosity of the oil and causing it to flow out. Also, the air near the surface is expanded, blowing oil out.

Possible Method for Reduction of Exudation: No practical control.

Factor 32: Length of storage time.

Discussion: Material lying horizontal in storage has sun on one side all day. This may cause bleeding as the period of storage is extended. Storage may also set to dry up some material.

Possible Method for Reduction of Exudation: Ordinarily no practical control. Rotation of stock to minimize storage time, when possible.

Factor 33: Variation of temperature in wood.

Discussion: Variation of temperature causes expansion and contraction in wood. This section may force out some preservative.

Possible Method for Reduction of Exudation: No practical control.

Factor 34: Accumulation of dust, sand, cinders, etc. on treated wood.

Discussion: Material in such location that it picks up a layer of blown material is likely to show bleeding. The accumulation apparently retards the evaporation of the preservative which flows to the surface.

Possible Method for Reduction of Exudation: No practical control.

Factor 35: Area where shipped.

Discussion: Generally there is more exudation in those areas where there is a great temperature change in one day, that is, cold nights and still, sunny days.

Possible Method for Reduction of Exudation: If poles are to be shipped to areas where bleeding is a particular problem, special precautions should be taken in treatment, such that it is minimized.

Wood preserving plants can do a great deal to conduct their operations in such a manner that exudation of oil-type preservatives will be minimized. Particular attention is called to some of the points previously discussed which warrant special emphasis. Uniformity of condition of the wood when treated, as affected by degree of staining and molding or by degree of seasoning and conditioning, (points 2 and 3 below) are probably the most important factors for the control of exudation. They are also important to effect a uniform service life and to eliminate early failure of individual pieces due to low retention or poor penetration.

1. Machine-trim round pieces.

2. Control staining and molding, and select material for treatment with an equal degree of staining and molding when possible.

3. Select material for treatment having the same degree of seasoning or condition the material in such a manner that the moisture content and distribution are as nearly uniform as possible.

4. Have the vacuum system adequate to obtain quick high vacuum on both the initial and final steps.

5. Keep the temperature of the preservative during the pressure period as high as possible. With creosote the cylinder temperature should be at 200° to 210°F. at the end of the pressure period.

6. If preservative is blown back, use minimum amount of air and never higher than the low point to which the pressure has fallen after release. Pumping back is generally desirable, particularly with thin sapwood species.

7. Where extra cleanliness is desired, use final steaming, final bath, boiling under final vacuum or other proved methods, but be sure that retention is not reduced to an amount below that specified. Overinjection may be required.

8. Avoid retreatment.

9. Keep the preservative clean. Cleanliness of used creosote may be improved by reducing the water content to about 0.5% and allowing the oils to settle in a tank, to reduce the percentage of benzol-insoluble matter in the used creosote.

10. Clean tanks frequently to prevent an accumulation in the bottom.

11. Prevent admixture with other preservatives.

12. Keep the water content low; a maximum of 2% is preferable.

13. Don't use preservative with too high distillation residue. For extra cleanliness, the residue of creosote used should not exceed about 30%.

14. Use an anti-blooming agent as necessary to prevent blooming where crystalline preservatives are dissolved in petroleum or other carrier; or use a carrier with a high enough distillation range to prevent blooming.

Soil-Block Bioassay of a Creosote Containing Pentachlorophenol

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Method of test, results, and observations and conclusions are related. The preliminary studies reported indicate that if pentachlorophenol is added to a creosote a substantial increase of the effectiveness of the creosote may be expected.

Introduction

NEW AND EXISTING wood preservatives are being tested continuously at the Bell Telephone Laboratories, Inc. The laboratory evaluation of preservatives by the soil-block method of bioassay is an important part of this test program. Any new and promising chemicals that appear to have the necessary attributes of a good wood preservative are subjected to the soil-block test. At the same time, samples of standard preservatives such as creosote and pentachlorophenol in petroleum which are being used in commercial treatments for the Bell System are examined regularly.

During 1947 a draft specification was prepared covering the fortification of creosote with pentachlorophenol and the draft was presented at the January, 1948, meeting of the Preservatives Committee of the American Wood-Preservers' Association by the Laboratories' representative. Four years later, during August, 1952, the tests described in this article were initiated to determine the wood-preserving qualities of a coal tar creosote in which pentachlorophenol crystals had been dissolved. Both of these are recognized wood preservatives and are being employed commercially in the United States and Canada. Pentachlorophenol is used generally in petroleum solution and to a limited extent by mixing equal parts by volume of the pentachlorophenol-petroleum solution with creosote.

Table I—ANALYSIS OF CREOSOTE NO. 9

Specific Gravity at 38°/15.5° C	1.007
Specific Gravity of 235–315° C fraction	1.000
Specific Gravity of 315–355° C fraction	1.002
Distillation	
to 210° C	1.59 g.
to 235° C	11.21 g.
to 270° C	29.31 g.
to 315° C	53.15 g.
to 355° C	78.06 g.
Residue above 355° C	21.62 g.
Total	99.68 g.
Benzol Insoluble	.20%
Sulfonation residue	15.01 ml/100 g., (210–355° C fraction)
Tar Acids (210° C to 235° C)	24.65 ml/100 g., (210–355° C fraction)
Coke Residue	.92%

Material Tested

The creosote selected for the study was an English vertical retort, coal tar creosote designated herewith as Creosote No. 9. An analysis of this creosote appears in Table I.

A weighed amount of the creosote was heated in a covered beaker to 140° F and enough recrystallized pentachlorophenol added to give a pentachlorophenol concentration of approximately 2.0 percent by weight. Purified rather than technical grade pentachlorophenol crystals were used in order that bioassay and analytical results could be interpreted in terms of pure pentachlorophenol. The creosote was stirred continuously until there was no indication of any undissolved crystals settling to the bottom of the beaker. There appeared to be complete solution of the pentachlorophenol within about one minute. The covered beaker containing this solution was allowed to stand for one day, then stirred, and a sample taken for the determination of pentachlorophenol content. A chloride determination was run on the creosote without penta as well as on the solution. The results of these analyses showed that the creosote contained 2.16 percent by weight pentachlorophenol.

Method of Test

For a detailed description of the soil-block technique as used at the Laboratories, the reader is referred to a recent publication by Colley.[1]

Twelve charges of 30 blocks each were treated to the following nominal retentions (2 charges at each retention) with the creosote-pentachlorophenol solution: 2, 3, 4, 5, 6 and 7 pounds of solution per cubic foot of wood. This range of retentions was selected based on a threshold for the creosote alone between 5 and 6 pounds per cubic foot as determined at the Laboratories on blocks weathered 60 days out-of-doors and using *Lentinus lepideus* (Madison 534) as the test organism. Madison 534 is a creosote tolerant organism. Soil-block tests on this same creosote conducted at the Forest Products Laboratory, Madison, Wisconsin, and reported by Duncan and Richards,[2] also gave a threshold between 5 and 6 pounds with Madison 534 for blocks weathered 60 days out-of-doors. Fifteen of the 30 blocks in each charge were selected for the experiment. These blocks, separated by glass beads, were strung on nylon thread and exposed on racks at the Chester field laboratory at Chester, New Jersey, for a period of 60 days beginning August 6, 1952. The remaining 15 blocks were used for other experiments which are not reported in this article. Fifteen of the weathered blocks from one charge at each retention level were designated for test against Madison 534, and the 15 blocks from the other charge at the same retention level were selected for test against *Lenzites trabea* (Madison 617). Madison 617 has a high tolerance for pentachlorophenol. Actually, only 10 of the 15 blocks in each group finally were exposed to the test organisms since 2 blocks in each group were placed in uninoculated bottles for the 90-day test period to permit determination of operational losses, and 3 blocks were held aside for chemical analyses in the event they might be required. The average retentions of treating solution and dry pentachlorophenol by blocks in the various retention groups as calculated on a weight basis are given in Table II. Also, the test organisms to which the different retention groups were exposed are designated in Table II.

Results

In Table III, the thresholds for the creosote-pentachlorophenol solution as determined by visual observation are compared (1) with thresholds obtained previously for Creosote No. 9 alone, and (2) with a 5 percent solution of pentachlorophenol in 2105 process oil (a light petroleum solvent). The threshold of a wood preservative is the minimum amount of preservative, based on initial retentions in the wood, which will prevent decay by a given test fungus. As is noted in Table III, some of the thresholds for the creosote and pentachlorophenol in 2105 process oil are based on U. S. Forest Products Laboratory (Madison) data as reported by Duncan and Richards[2] for the creosote, and as reported by Duncan[3] for the pentachlorophenol-petroleum solution. The threshold for the creosote-pentachlorophenol solution was found to be between 1.9 and 2.8 pounds with Madison 534 as the test organism, and between 2.8 and 3.9 pounds with Madison 617. The weight loss data showed that there was more weight loss in blocks exposed to Madison 617 than in blocks tested against Madison 534.

Observations and Conclusions

The addition of 2.16 percent pentachlorophenol to Creosote No. 9 increased the effectiveness of the creosote about 50 to 60 percent in terms of the test fungus Madison 534, and 20 to 25 percent in the case of Madison 617. The fact that a one pound higher threshold was obtained with Madison 617 suggests that with a solution of creosote and pentachlorophenol, the highest threshold is obtained with Madison 617, and so it is the critical test fungus. In like manner, previous bioassay results reported from the Forest Products Laboratory at Madison by Duncan[3] showed that Madison 534 was more affected by the presence of pentachlorophenol than Madison 617 was affected by creosote in pentachlorophenol-petroleum-creosote solutions.

In a paper presented recently before the 1953 convention of the American Wood-Preservers' Association, Duncan[4] reported on outdoor weathering studies using blocks treated with a specific creosote. Her data showed that the losses of the creosote from treated blocks, as well as the threshold for the creosote, varied depending on the season during which the blocks were weathered. The thresholds reported for Creosote No. 9 without any pentachlorophenol addition as determined at Bell Laboratories were obtained on blocks weathered 60 days out-of-doors beginning in January. The Madison threshold data presented in Table III on the same creosote are based on blocks weathered 60 days out-of-doors beginning in July. The threshold in both cases was between 5.1 and 6.0 pounds per cubic foot. This does not mean that no difference existed in the threshold. It means merely that there was not enough difference in the case of this particular oil to result in the thresholds falling outside of the 5.1 and 6.0 pound limits reported in this paper. These data are not intended to imply nor do they demonstrate, that a specific difference in the threshold of this creosote as determined at the two locations does not exist within the limits cited due to the different seasons of weathering.

An interesting comparison can be drawn from the data in Table III regarding the degree of increased effectiveness of the creosote based on the amount of pentachlorophenol added. Actually, two comparisons are necessary—the first based on results with Madison 534 and the second with Madison 617.

In previous tests with Madison 534, the threshold of the creosote alone was between 5.1 and 6.0 pounds. In this study, when 2.16 percent pentachlorophenol was added, the threshold

dropped to between 2 and 3 pounds. This means that when the creosote contained 2.16 percent pentachlorophenol, 50 to 60 percent less creosote gave the same degree of protection. This is explained presumably by the fact that in the case of the creosote-pentachlorophenol solution, there was .04 to .06 pound of dry pentachlorophenol per cubic foot of wood present at the threshold point. Normally with Madison 534 as the test organism the threshold for straight pentachlorophenol in petroleum lies between .10 and .15 pound of pentachlorophenol per cubic foot of wood. In the case of the creosote containing 2.16 percent pentachlorophenol, the wood contained at threshold approximately 40 to 50 percent of the pentachlorophenol normally present in wood at the threshold point for pentachlorophenol. In other words, as might be expected in the absence of any synergistic effect, the increased preservative value received was equal to the amount of preservative value added in terms of pentachlorophenol.

In the second case—with Madison 617 as the test organism—the same line of reasoning can be applied. The threshold of Creosote No. 9 tested alone fell between 4 and 5 pounds (Madison data). In this test when the same creosote contained 2.16 percent pentachlorophenol the threshold dropped to between 3 and 4 pounds. In other words, 20 to 25 percent less of the creosote-pentachlorophenol solution was required for the same degree of protection. In the creosote-pentachlorophenol solution there was at the threshold, .06 to .08 pound of dry pentachlorophenol per cubic foot of wood. This was 30 to 32 percent of the .20 to .25 pounds of pentachlorophenol present at the threshold point for a straight pentachlorophenol-petroleum solution. Therefore, in the case of test fungus Madison 617, 20 to 25 percent less creosote was required when it contained 2.16 percent pentachlorophenol. Thirty to 32 percent of the pentachlorophenol actually present at the threshold point for straight pentachlorophenol was contained in the wood treated with the creosote-pentachlorophenol solution at the threshold point. There is a fair degree of balance in this case between the increased preservation received in terms of the amount of pentachlorophenol added. However, there is some indication in the figures cited above that pound for pound pentachlorophenol in creosote is not quite as effective against *Lenzites trabea* (Madison 617) as straight pentachlorophenol in a petroleum carrier. Even so, the data show that there is a good deal of value in including pentachlorophenol in the creosote, particularly against *Lentinus lepideus*.

These preliminary studies indicate that if pentachlorophenol is added to a creosote a substantial increase in the effectiveness of the creosote may be expected. More extensive soil-block tests are under way involving the fortification of other creosotes with pentachlorophenol.

Table II—AVERAGE CALCULATED RETENTIONS OF PRESERVATIVE SOLUTION AND DRY PENTACHLOROPHENOL BY BLOCKS IN THE VARIOUS RETENTION GROUPS, AND THE TEST ORGANISMS USED

Retention Groups—Average Retention of Solution lbs./cu. ft.	Retention Groups—Average Retention of Dry Pentachlorophenol lbs./cu. ft.	Blocks in Retention Groups No.	Test Fungus
1.89	.041	10	Madison 534
1.88	.041	10	Madison 617
2.81	.061	10	Madison 534
2.81	.061	10	Madison 617
3.77	.082	10	Madison 534
3.88	.084	10	Madison 617
4.94	.107	10	Madison 534
4.87	.105	10	Madison 617
5.84	.126	10	Madison 534
5.87	.127	10	Madison 617
7.01	.152	10	Madison 534
6.96	.150	10	Madison 617

Table III—THRESHOLD RETENTIONS OF CREOSOTE NO. 9 PLUS 2.16 PERCENT PENTACHLOROPHENOL COMPARED WITH THRESHOLDS FOR CREOSOTE NO. 9, AND PENTACHLOROPHENOL IN 2105 PROCESS OIL

Preservative	Test Fungus	Threshold (Outdoor Weathered Blocks) Preservative Solution lbs. cu. ft.	Dry Pentachlorophenol lbs. cu. ft.
Creosote No. 9 Plus 2.16% Pentachlorophenol	Madison 534	1.9 to 2.8	.04 to .06
Creosote No. 9	Madison 534	5.1 to 6.0	
5% Pentachlorophenol in 2105 process oil	Madison 534	2 to3*	.10 to .15*
Creosote No. 9 Plus 2.16% Pentachlorophenol	Madison 617	2.8 to 3.9	.06 to .08
Creosote No. 9	Madison 617	4 to 5*	
5% Pentachlorophenol in 2105 process oil	Madison 617	4 to 5	.20 to .25

*Macison data.

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Loading and Unloading of Multiple Opening Hot Presses[1]

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Advances and problems in development of handling equipment to load and unload multiple opening hot presses is described, including automatic charger and automatic panel remover mechanism.

ANY DISCUSSION COVERING LOADING and unloading equipment must be prefaced with some reference to the multiple-opening hot press, as the loading and unloading operations do not begin or end of themselves, but rather are dependent upon and operate in conjunction with the multiple-opening hot press.

Multiple-opening hot presses were built and used in Europe long before they were used in the United States. The Siempelkamp people, of Germany, claim 70 years as manufacturers of these units. One of the first Siempelkamp presses in this country was installed at M&M Plywood Co. and is still in operation at St. Johns. It is of interest to note that because this press has a very large plate size, mechanized loading was required.

Press manufacturers in our country have made great strides in the manufacture of press machinery; the utilization of mechanized loading and unloading devices has advanced much beyond that in foreign countries, where hand loading is still prevalent. Large production units in Europe are fully mechanized, as for example, a novoply operation in Germany has a 30-opening press with loading and unloading equipment. In Sweden many rack-type Chargers and Receivers are in use employing a puller ram in the Receiver, as will be described later in this paper. In the United States, however, mechanization is a normal trend and is a by-word in all our industry.

Manufacturers of plywood and hardboard, utilizing multiple-opening hot presses, pointed up the need for an automatic means of loading and unloading these presses. Such mechanization is more than time- and labor-saving machinery. Basically, a loader and unloader are conversion, or transition machines, which interrupt the continuous flow of the product, accumulate it for the batch process, and then re-convert the batch back into a continuous flow. The books of plywood, or the mats of hardboard, arrive at the press loading device individually and must, therefore, be accumulated for the hot press which is a batch-type machine. As the economics of these operations dictated more press openings and larger sizes, so the need for intermediate or conversion units became more evident.

The nomenclature of specially designed equipment is somewhat of a problem, usually. For the sake of clarification we refer to such conversion units as Chargers and Receivers, rather than loaders and unloaders. To all practical purposes the Charger and Receiver are similar machines, merely working in opposite direction to one another.

Having established the basic functions of the Charger and the Receiver, the next problem is the decision as to whether or not these units are required. This decision is naturally dependent upon the operation itself, and calls for consultation with a machinery design engineer.

Reliability Necessary

The usual method is to duplicate the manual operation by means of motors, limit switches, a few cams; add a bit of paint; and thereby produce a machine which will do exactly what a man can do. The only thing left is to put a fancy price tag on the machine and sell it. Seriously, such machinery must be reliable and must eliminate human failure, as well as add the element of safety not possible in manual operation.

The decision as to whether automatic chargers and receivers are required is dependent upon the operation itself. Figure 1 is a schematic drawing showing the simplest loading and unloading system in use, which is one utilizing elevators on either side and directly adjacent to the press. The elevator on the loading side is called the feeder elevator, and on the unloading side is termed an offbearing elevator. Actually, the two elevators are exactly the same. This particular drawing shows an electric four-corner post-type lift, but the mechanics of raising and lowering two men and their load can vary greatly.

In this system the press operator and his assistant stand in wells at either end of the books of plywood, or flat sheets. Either the elevator is raised to the top and loading started after the press has been opened completely and the cured panels are removed from the press (by hand), or the operator can start loading the press from the bottom and save a few seconds by starting to close the press while the top few openings are being loaded.

Figure 2 shows much the same type of manual operation in which the lifting means consists of a hydraulic ram and pumping unit. In a number of installations press manufacturers have provided rams for both the feed and offbearing sides of the press, the ram casings being an actual part of the press base, and the hydraulic supply for the feed and offbearer elevators being taken from the same pumping unit which closes the press.

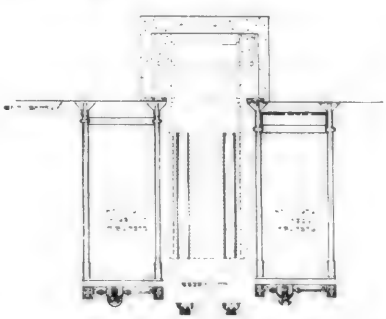

Figure 1.—Hot press feeding system utilizing elevators for loading and unloading.

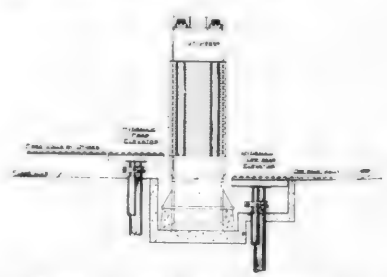

Figure 2.—Same type of operation as in Figure 1, except that hydraulic rams are used to power elevators.

[1] Presented at meeting of the Forest Products Research Society, Pacific Northwest Section, April 28, 1953, at Eugene, Ore.

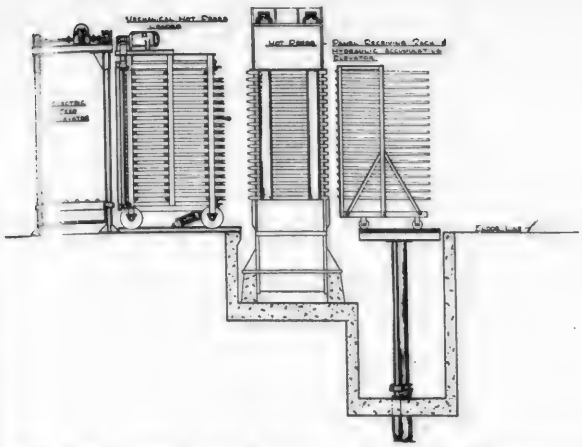

Figure 3.—In simplest type of mechanical loader panels are pushed onto the receiving rack by manpower.

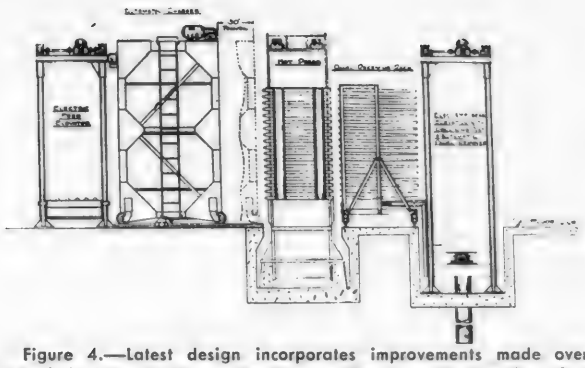

Figure 4.—Latest design incorporates improvements made over a period of years. Charger backs away from press two or three feet to minimize effects of heat radiation on panels in charger.

Aside from the fact that it is slow and that manpower is required, the main disadvantage of this type of loading and unloading is that when the press has a large number of openings, the first book placed on the press plates is subjected to the heat of the plates, but cannot be put under pressure until all openings are loaded and, therefore, all panels have varying times under heat before being subjected to pressure, and pre-curing is a result. The ultra-modern fast-curing resins, both the phenolic and resorcinol types, are extremely critical to this condition. Any improvements in the proper application of heat and pressure to the glue line undoubtedly would be appreciated by glue manufacturers. The obvious answer to this problem is the simultaneous loading of all of the plates at the same time, and this is the next natural advancement.

In order to explain the mechanization of charging and receiving panels to and from a hot press, the various types have been separated into three divisions:

First, the type of unit requiring a pit; second, the charger and receiver mounted directly on the floor and not requiring pits, but with an additional elevator in front of the charger; and third, the type used in some hardboard installations, which is self-loading and self-elevating.

The unit requiring a pit usually is a mechanical device consisting of a rack or magazine deck section, capable of vertical travel, which accepts individual books or mats from a conveyor at a given distance from the floor, and then elevates so the next panel will enter a different opening. In this manner the elevator upon which the accumulating racks are mounted accepts all of the mats or books required for one press charge. This is done in a number of ways. One of our largest hardboard producers uses buggies, or racks, which can be transported around the entire plant and placed on an elevator some distance away from the press, where the mats can be accumulated as required, and then transported as a group to the press. Basically, all equipment in this first group includes such a buggy which travels up and down on an elevator. This, of course, is no problem, but the actual charging of the press, and conversely the discharging of the cured panels from the press, does pose a great problem. In some cases the presses have puller devices which attach to the mat, or to the cauls or the screens, and load and unload similarly to the operation of a common window shade going on and off its roll.

Other similar systems which might be classified as self-charging presses are required where the mat cannot support itself, or where there are no supporting cauls and each press plate has a screen which entirely surrounds the plate and is actuated as the press is opened. This movement of the screen around a press plate not only carries the finished panel out of the press and into a Receiver, but the magazine loader has a comparable system of screens, which when timed with the press screens allows for the transportation of the uncured mats out of the charger and into the press. There are numerous variations of this system, particularly in the Northwest in some of the recent hardboard installations.

These chargers and receivers become more complicated when the material which is to be pressed is not self-supporting. In such cases, not only the product itself, but the supporting means must be considered.

In granular hardboard manufacture, the nature of material used necessitates not only a support on the bottom, but the sides and ends also must be enclosed. This pan must be located accurately within the confines of the press plates, so that the press plate itself acts as a male die, and the pan becomes a female die. The location of the pan must be such that the press plate does not bear on the pan edges. In most cases, the pan is slightly larger in area than the press plate.

In one particular application of this kind, a very complicated charger actually couples individual pusher bars for each opening with extensions on the pan flanges, and not only locates the pan of uncured material properly in the press, but the same bar withdraws the cured boards out of the press from the same side.

Such an operation is accomplished by using the charger and receiver as one unit, with 20 openings, used in conjunction with a 10-opening hot press. This is an extremely complicated system not recommended for a standard loading arrangement, but necessitated by the twisted layout of the plant. This installation is mentioned to point up the dependency of loading and unloading equipment on other factors, and the diversity of these units now in operation. Probably the most common charger and receiver units in use, where cauls are required to support the product, are what are known as rack-type units.

This unit primarily consists of one rack having a number of supporting decks, equal to the number of openings in the press and set, of course, at the same pitch as the press. Down the center of these decks is a gap which will allow for the movement of a poker ram or pusher arm. In the normal operation of this type of unit, which is used in many of the dry-process hardboard plants, the magazine decks are moved vertically in and out of the pit so that they normally start their loading operation when they are in the fully lowered position. As the caul-carried material

is received from an incoming conveyor, the caul itself automatically trips a limit switch which causes the elevator to lift the deck one pitch, thereby placing the next opening opposite the incoming conveyor ready for the next charge to be received.

This operation is repeated until the entire press load of uncured board-caul combinations is accumulated in the Charger in an interval timed to the pressing cycle. The receiver is identical to the Charger, but has a puller ram in place of a pusher ram, which engages tabs on the cauls as soon as the press is opened, and discharges the entire press load of caul-board combinations simultaneously. At the same time the pusher bar travels forward and the mat-caul combinations are charged simultaneously into the press. This is probably the simplest and least expensive method of automatically charging and discharging a press. Even so, there are any number of difficulties involved in such a system.

For example, a very complicated system must be devised so that even in a semi-automatic operation where a man controls the various functions of the machinery, the electrical system must out-think the man to the degree that it will not allow damage to the machinery or to the board or cauls, not to mention overall plant morale. This could happen if the operator were to push the wrong button or become confused in his duties.

Further than this, certain electrical or mechanical functions can fail. For instance if the receiver, which starts the complete loading and unloading cycle first, draws a finished caul-board combination only partially out of the press, and then for some reason stops, say because of a burned-out motor, and the Charger at the same time is inserting a load of unfinished mat-caul combinations into the press, the two would meet somewhere in the press and you can imagine what would happen. The damaging of a $300 or $400 stainless steel caul—or, worse yet, a complete set of stainless steel cauls—sounds much louder, and looks much worse to the machinery manufacturer than to anyone else. It is imperative, therefore, that a practically fool-proof system be devised to cut down the possible errors in this type of equipment.

A variation of the use of the magazine rack-type Charger, having a pusher bar to load the uncured panels simultaneously into a press, is the type of unit recently installed in a plywood plant in Oregon. In this case, the magazine rack does not have a gap down the center of the supporting trays, but has a poker car which is movable, with long fingers mounted upon its front face, one for each opening. The poker car contacts the trailing edge of uncured plywood books and charges the press simultaneously by means of these poker car fingers.

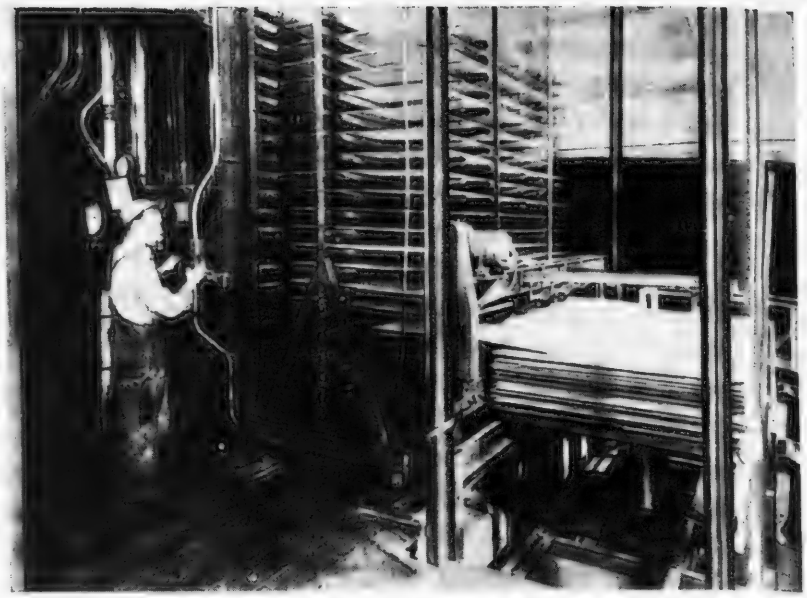

Figure 5.—Panels are being removed automatically from the receiving rack and stack on a hydraulic declining platform.

The second general division comprises the mechanical-type chargers which do not require pits and are mounted directly on the floor. These are the well-known plywood chargers which are common to many plywood operations in the Pacific Northwest. This is a familiar phase of plywood manufacture; the receiving of an entire press charge of uncured books from the glue spreader; this book or stack of books then placed on a feed elevator, floor mounted, which the operators ride, placing the individual books into the various openings of the charger.

There are a number of different types of mechanical and automatic chargers in this group. Some have a mechanical function, such as a poker car or a car with poker fingers. In some instances, in place of an individual poker car with long fingers, which simultaneously charge the press with the uncured panels, the poker fingers are a part of the charger itself. In this type the fingers are beyond the ends of the tray openings when loading. When in operation the fingers, or pusher bars, come down the front edge of the charger, make a right angle turn and contact the books after the turn, then charge them directly into the press.

There must be some sort of receiving device with each loading arrangement, since with this equipment each unit must have its corresponding functional counterpart; that is, specific chargers require specific receivers.

In considering mechanical loaders it is necessary to devise some means of removing finished plywood panels from the press before the uncured books are inserted. Figure 3 illustrates probably the simplest and most common method utilized, which is for two men simply to push out the finished panels with a stick as soon as the press opens. The panels go through the press and out the offbearing side to allow two other operators (or the same two) to grasp each panel and pull it into a receiving rack. Not far from Eugene (Ore.) an automatic device has been tested recently to push these cured panels out far enough by mechanical means so that only two operators are required to remove the plywood the remaining distance.

Figure 4 shows a design that incorporates the improvements which have developed over a period of years. The entire charger is capable of backing away from the press two or three feet, thereby getting out of range of heat radiation from the press plates when the press is closed. Many operators believe this to be a very important feature for the prevention of pre-curing of the leading edges of the uncured books which are being accumulated in the charger for the next press load.

Another feature of such a unit is that the books actually are carried into the press openings on trays which contact the finished or cured plywood panels in the press, and push them out the offbearing side into a receiving rack. Pusher bars, which previously

were retracted, now move out and hold the plywood in position in relation to the press plates while the tray is being removed. After the plywood books are clear of the tray, the pusher bars retract and the entire mechanism is clear for press closing.

Referring to Figure 5 it is noted that the receiving process can also be mechanized to such an extent that labor is cut to a minimum. Here is seen how the panels can be removed automatically from the receiving rack and stacked on a hydraulic declining platform.

This automatic panel remover includes a system of belts coming up from a lower level. These belts are moving and contact the bottom surface of the plywood in the rack; friction causes the plywood to move from the receiving rack to the offbearing elevator.

The next group—the self-elevating and self-declining types of units—became a requirement in the development of the hardboard industry when the time element became a vital factor, and the manufacture of 16-foot long boards was begun. These units are mounted directly on the floor and combine an accumulating rack and an elevator.

The Self-elevating charger has two chain deck elements, and in addition there is a built-in conveyor which runs the full length of the unit between the decks. This conveyor is aligned with the incoming conveyor and moves the mat-caul combinations the full length of the charger, where a limit switch causes the conveyor motor to stop and the decks to raise one pitch. This operation is repeated until a total press charge is accumulated. The pusher ram then charges the press, starting slightly after its companion unit, the Self-declining receiver, has engaged the finished board-caul combinations in the press and withdrawn them into the decks of the receiver.

The most important feature of the self-elevating unit is that the conveyor is actually one complete press pitch below the bottom opening of the hot press, and the pusher bar covers only the openings which correspond to the hot press. This allows the loading of the first board for the following press cycle while the simultaneous charging of the caul-board combinations is taking place. A considerable amount of time is saved in this way. Actually, this type charger and receiver can have as many as four extra, or false, openings which can be loaded by a tipple conveyor. It is obvious that a considerable amount of time can be saved in the actual charging of the press, as a continuous flow of mat-caul combinations can be accepted in the false openings during the charging interval. This is a method machinery manufacturers and inventors utilize to widen the use of this machinery, as it is, in effect, a loader for the charger.

Such units naturally are justified only for extremely high-production operations where the time element is a very necessary and important feature, and where possibility of human error must be avoided.

The loading and unloading of multiple-opening hot presses is not purely a mechanical matter, involving pushing plywood panels, or hardboard cauls or pans into the press at one end, and removing them from the press at the other. There are many factors to be considered, including the design and application of the equipment, speed of elevation, speeds of charging and discharging, acceleration and deceleration of the pusher rams, various characteristics of the product, and the existing plant layouts.

The Cyclical Exposure Test as a Tool in Laminating Quality Control[1]

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Experience with the cyclical exposure test as employed at Puget Sound Naval Shipyard is related, with special emphasis on how time required for testing has been reduced.

As adhesives more resistant to severe service conditions were developed and glued material was considered for new applications investigators exercised considerable ingenuity in developing tests which would forecast performance under the ever widening exposure conditions. Because "adhesive durability" is a relative term which means that the bond will hold for the life of the product under the intended usage, it has been natural to relate the tests to particular types of products. Since plywood was one of the earliest glued products, much of the research has been directed to this type of construction. To enable comparisons, many of the durability tests were standardized on birch veneer and the exposure conditions have included:

- Natural weathering
- Boiling in water
- Continuous soaking in water at room temperature
- Alternate soaking and drying at room temperature
- Alternate high temperature with low humidity and low temperature with high humidity
- Continuous high temperature with low or high humidity

The wide variety of hardwood and softwood plywood available today is good evidence that these and other tests have been used to advantage.

Laminating, A New Field

Laminating is a newer field of wood gluing with the grain of all layers or laminae running parallel. Also the laminaes are usually much thicker than those of plywood. The nature of laminated material prompted the development of tests which would more nearly duplicate the stresses developed during various service conditions.

The Navy Department's Bureau of Ships has encouraged much research work on water-proof adhesives for laminating. Many of the smaller vessels are built of wood and must be capable of dependable service from one climatic extreme to the other. In recent years, large solid sizes have not been available in sufficient quantity to meet needs and the Navy has depended more on laminating. Also new designs have evolved which take advantage of the unique strength possibilities of laminated material. Under Navy spon-

[1] Presented at Forest Products Research Society, Pacific Northwest Section Meeting, October 13, 1953, Bremerton, Washington.

sorship, considerable research has been conducted on the gluing of white oak —a wood not easily bonded. In some of this development work white oak test beams laminated with several different adhesives cured under various temperature conditions have been subjected to:

Natural weathering
Continuous soaking in fresh water
Continuous soaking in salt water
Alternate soaking and drying using fresh water or salt water and severe drying conditions
Block shear tests before exposure and after various time intervals

Some early results indicated that continuous soaking in fresh or salt water did not appreciably affect glue lines of most test beams made with properly cured thermosetting resin adhesives of phenol, resorcinol or melamine base, and little delamination (failure of the glue line) was noted. On the other hand, natural weathering or alternate wetting and drying tests produced severe delamination in some of the test beams but very little in others. Thus a means of detecting weak glue lines was found. Or, stating it in another way, exposure conditions were found which were beyond the ability of some of the particular adhesives used. The results of block shear tests did not correlate well with natural weathering or cyclical tests except that in beams showing high delamination values average wood failure was usually below 75 percent on the dry block shear. The dry block shear was therefore considered to be useful for determining the initial bond strength, but natural weathering or cyclical tests gave a better indication of resistance to severe exposure conditions over a long period of time because of the stresses produced by wetting and uncontrolled drying.

180-Day and 21-Day Tests

Eventually a three cycle alternate soaking and drying test requiring 180 days was developed and became incorporated in a joint Army-Navy Specification known as JAN-A-397 dated 20 September 1946. This specification was used to determine the suitability of water-proof thermosetting resin laminating adhesives of phenol, resorcinol, and melamine base in the room temperature and intermediate temperature range (1).* As used in JAN-A-397, the test was performed on small beams with six white oak laminae ¾ to ⅞-inch thick, 6 inches wide and 48 inches long. Each cycle consisted of soaking the beams in sea water or fresh water for 30 days, then drying in summer weather or a heated room (about 80° F.) for 30 days. Extent of delamination was expressed as a percentage of the total length of glue line exposed on the ends of the test beams. A non-passing sample was one in which delamination in excess of 10 percent was observed any time during the test.

But 180 days was too long a period to wait for results, even on adhesive qualification tests. During other studies, details of the test were observed which led to the development of a shorter one known as the 21-day test. In one version, three-inch long specimens cut from laminated test beams were subjected to three cycles of alternate soaking and drying. The specimens were placed in a pressure vessel and a vacuum of 20 to 25 inches of mercury was drawn for two hours; then without breaking the vacuum, fresh water at room temperature was admitted until the specimens were covered, and air pressure of 75 psi was then applied for two hours. Vacuum and pressure were each repeated for two hours to make a total of 8 hours impregnation. The specimens were then allowed to remain in water at atmospheric pressure for 16 hours to give a total soaking time of 24 hours.

By this method the average moisture content of the specimens was brought well above the fiber saturation point and produced a swollen condition. The soaked specimens were then dried for six days in a room with good circulation of air at 80° F. and 30 percent relative humidity in order to induce severe stresses perpendicular to the glue lines by rapidly drying the end-grain surfaces. The soaking and drying constituted one cycle and the procedure was repeated until three cycles had been performed. Delamination was measured at the time during the drying of the third cycle when it was at a maximum (usually during the fourth day). Controlled comparisons of the 21-day test with four years' natural weathering indicated that on oak and maple, somewhat higher delamination values probably would be obtained in prolonged natural weathering. However, consistent parallel trends were apparent and the 21-day test proved useful for detecting poor glue lines. The comparisons also included Douglas fir and Southern yellow pine and indicated that a difference between species might be expected.

21-Day Test Saves Time

The 21-day test replaced the 180-day test by an amendment to JAN-A-397 dated 28 October 1948 (2). A later revision designated as MIL-A-397A further elaborated the specimen spacing and air velocity during drying so that the end-grain surfaces were at least two inches apart and parallel to air flow. An air velocity of at least 200 feet per minute was specified (3). Adhesive qualifications using the 21-day test allowed a maximum average delamination of ten percent on white oak. The 21-day test meant a saving of 159 days in determining the suitability of an adhesive for marine service laminating. This saving was especially important as the present wooden minesweeper construction program got underway and tests of additional adhesives, particularly of the resorcinol and modified resorcinol types, were authorized to supplement the few on the qualified products list for JAN-A-397.

At the beginning of the minesweeper program the 21-day test was used along with the dry block shear for approval of white oak frames, stems, keels, longitudinals, transom stiffeners, knees, and other members produced in accordance with Military Specification MIL-O-15154 and later MIL-W-15154A (4) (5). The members were considered acceptable if not more than 10 percent delamination occurred in the test. Douglas fir members laminated under MIL-F-2038 (6) were tested by the dry block shear test only because of the relative ease with which it can be glued. However, such critical Douglas fir members as stems, keels, and horn timbers were also subjected to the 21-day test when requested by the cognizant Navy inspector. Forest Products Laboratory, Timber Engineering Company, and Puget Sound Naval Shipyard were designated as the testing facilities for the mid-west, east coast, and west coast respectively.

12-Day Test Replaces 21-Day Test

Even though the 21-day test was a big improvement over the 180-day test for adhesive qualifications, it was often too long for close laminating quality control. In the early stages when many non-passing test results were being reported, the close building schedules necessitated production with the results of process changes being unknown for an appreciable length of time. Retests were authorized when sufficient material was available. Often the members were erected by the time the first test result was reported and if the second test was also a failure, it meant the member had to be removed from the erected framework, with the resultant loss of material and time. However, when sufficient material existed for additional tests, the Navy usually accepted a member whenever a passing value on retesting was obtained pro-

* Numbers in ( ) refer to references cited at end of paper.

vided there was good evidence to indicate the non-passing values may not have represented the member because of sample location. The close building schedules definitely pointed up the need for a still faster test than the 21-day.

During the period when the 21-day test was being used for adhesive qualifications and other studies, it had been observed that checking on the end surfaces of white oak specimens was usually at a maximum during the fourth day of drying. By limiting drying to 3⅜ days at slightly drier conditions, submerging the specimens prior to the first vacuum period, and eliminating the overnight soaking at atmospheric pressure, the test period was reduced to 12 days for three cycles. In each cycle, soaking required 8 hours with vacuum and pressure alternating every two hours. Drying conditions were 80° F. and 25 to 30 percent relative humidity. Air velocity and specimen spacing were the same as for the 21-day test—200 feet per minute with at least two inches between specimens located so that end-grain surfaces paralleled air flow. This test became ASTM tentative test No. D-1101-50T (6). Controlled comparison tests indicated the 12-day and 21-day test produced similar results. By letter, the Bureau of Ships authorized the use of the 12-day test for acceptance of laminated members for the minesweeper program and also for adhesive qualification approval.

Some of the white oak samples from early minesweeper production developed a high percentage of delamination in the cyclical tests. Failures were often traced to use of unapproved adhesives; poor processing, including surfacing, spreading, clamping, curing, etc.; and to samples being cut from beyond the well-clamped area. Such failures were partially expected due to the many new laminators and the fact that many of the members were larger and more complicated than had previously been made with white oak. The need for closer processing control was emphasized by the non-passing test values.

Use of the 12-Day Test at Puget Sound Naval Shipyard

The shortening of the test to 12 days was a big help and saved valuable time in an urgent program where high quality glue lines were essential. From January 1952 to October 1953 the Research and Test Engineering Laboratory at Puget Sound Naval Shipyard tested almost 4000 samples from minesweeper members. At the peak, almost 300 samples were in various stages of the test at one time. The need for facilities with considerable capacity became apparent and existing soaking equipment was supplemented with quickly built dryers, additional personnel were obtained and methods of handling were developed to meet the situation. This volume of samples required close control through all phases of the test in order that report schedules could be maintained. Following is a description of the equipment and methods:

Soaking: 1. Two inter-connected horizontal autoclaves fabricated from 14 inch steel pipe with vacuum pump, fresh water supply, and compressed air supply. Specimens are loaded on angle-iron racks and separated by stickers.

2. Vacuum pump runs continuously and pulls the autoclaves down to 27 inches of mercury within 5 minutes.

3. Air pressure varies between 85 and 95 psi.

4. Soaking period is 7½ to 7¾ hours divided equally into two alternating periods of vacuum and two of pressure.

Drying: 1. Dryers are plywood cabinets with four shelves acting as independent air ducts fitted with fans, heaters, and exhaust ports.

2. Dry compressed air is added to the recirculating air as a means of reducing the initial high relative humidity and maintaining it in the desired range of 25 to 30 percent.

3. Heaters are thermostatically controlled to maintain temperature between 80° and 85° F.

4. Specimens are placed in three rows with two-inch spacing between rows. Air flow is parallel to end-grain surfaces.

5. Canvas flaps confine air flow to spaces between specimens.

6. Drying continues for 88 hours (3⅜ days).

Evaluation: 1. Glue lines are examined under binocular microscope and delamination (glue failure) is marked with a bracket . Wood failure, even though close to the glue line is not considered delamination.

2. The lengths of individual delaminations are accumulated on dividers to give total delamination for each glue line on each end surface of the specimen. Isolated delaminations less than 0.1 of an inch long are ignored. To be considered "isolated", the delamination must be at least 0.2 inch from any other glue failure in the same glue line.

3. The accumulated length of delamination and the length of each glue line on each end surface is measured and recorded to the nearest 0.05 inch.

4. The percent delamination for each specimen is determined by dividing the total length of delamination on both end surfaces of the specimen by the total length of all glue lines.

The 12-day test as conducted at Puget Sound Naval Shipyard and elsewhere has performed a valuable function—assuring high quality laminated white oak members designed for strenuous duty. It has made possible the identification of members with doubtful ability to withstand severe exposure conditions for long periods of time; and thus has helped to provide members for improved wood vessels which attempt to take better advantage of wood's strength than any vessels of the past. It is also being used for quality control of laminated Teak–Douglas fir decking produced at Puget Sound Naval Shipyard and elsewhere as well as a qualification test under various laminating specifications mentioned later.

Aspects of 12-Day Test

As usual, with gains there are sacrifices. The 12-day test indicates the probable durability of laminated members intended for severe exposure conditions, but requires time that has to be allowed at some stage between end of cure and ultimate use. Laminating requires the control of a considerable number of variables; some of which are more thoroughly understood than others. The requirements for producing high quality durable joints for severe service conditions are fairly well known. Where non-passing values are being obtained, a few things are usually apparent which may be the source of difficulty. Whether it is necessary to suspend production while awaiting test results depends on the nature of the laminating job and the improvements suggested. Urgency of the minesweeper program required that laminating continue even though it meant possible loss of subsequent machining cost as well as material. In some cases, this practice resulted in continued production of material below standard. However, even the most stubborn difficulties were eventually isolated with the help of the 12-day test. Without the 12-day test there would have been misleading assurance that the members were of high quality as the dry block shear in most cases gave passing results. In more recent work, production was stopped pending results of process changes.

At the present time the 12-day test is a sensitive test for determining the effect of process changes in laminating and thus is performing as a most useful tool in laminating quality control. The 12-day test is now a part of several Military Specifications including MIL-A-397B, MIL-W-15154, MIL-W-17445 and MIL-D-16285B which are respectively, specifications for water-proof laminating adhesives and laminated members of white oak, pre-

servative-treated oak (including red and white) and Teak combined with Douglas fir (8) (5) (9) (10). In each specification the maximum allowable delamination is related to species and type of joint as shown in Table I. The test is highly regarded and is in keeping with the Navy's determination to improve the life span of its wood ships and boats through the use of high quality laminated members and preservative treatments.

At the beginning of a laminating program or when changes are made in processing, it is evident that testing should be more intensive than when production has smoothed out and the desired quality level is being maintained. This approach is incorporated in the very latest laminating specifications released—MIL-W-0015154B for white oak (11) and MIL-W-2038B for Douglas fir (12). These newest specifications require a high sampling level at the beginning of production and a lower sampling level when consistently passing values are being obtained in 12-day test and dry block shear test provided that close process inspection is available. Table I also lists maximum allowable delamination values for these new specifications.

However, the name "12-day test" is something of a misnomer which implies that results are available in 12 days. Each cycle requires 4 days and if the laboratory performing the test is working on a 7-day basis, only 12 days are required for three cycles. But if a 5-day week is practiced, the test requires at least 14 to 15 days. Supplemental, work of specimen preparation and reporting require additional time so that the total is quite a bit longer than 12 days. Although to date the 12-day test is the shortest available, the need for a quicker test is apparent, and the search goes on.

Shortening the 12-Day Test

One approach to a shorter test is to use fewer cycles. It has been found by various investigations that a fairly definite relationship exists between the extent of delamination produced in each cycle. On an experimental basis the Bureau of Ships has authorized acceptance of white oak members from a limited number of laminators using two cycles of the 12-day test. Members tested are accepted if delamination is not over five percent at the end of the second cycle. To date, Puget Sound has tested about 55 members in this manner. Of these, only four were above five percent on second cycle and of those only one went slightly above 10 percent on third cycle. To extend the same thinking to the use of one cycle, data from present testing are being accumulated. At present these are not extensive enough to allow full use of one cycle, but the indication is that suitable limits can be set up to allow one cycle evaluation with considerable confidence.

Other ways to more rapid tests may be through the use of drying conditions with lower relative humidities and higher temperatures. A few tests using higher temperature and lower relative humidity have been made on specimens from test beams known to be doubtful. Although correlations values are not available at this time, delamination was produced and the results look promising. Shorter soaking time may also be possible for some species. These and other possibilities are being considered and their limitations explored. In the past, when the need for new tests arose, they have usually been developed and there is no doubt that more rapid exposure tests will be found. While shorter tests are being worked out, the present state of development reached by the 12-day test in a relatively short time is being extended. Some comparisons between laboratories have been made which should lead toward standardization of methods and equipment.

As indicated previously, the 12-day test has become a well respected tool for determining the quality of laminated material which has been bonded with water-proof adhesives and is a part of several military specifications. Even though several days are required, it offers a chance to predict the performance of laminated members by accelerating service conditions.

Table I

Specification	Species	Type of Glue Joint	Maximum Allowable Delamination, percent*
MIL-A-397B	White oak	Face	8
MIL-W-15154A Interim	White oak	All	10
MIL-W-17445	Pressure Preservative-treated red or white oak	All	10
MIL-D-16285B	Teak	Edge	8
		End	10
	Teak to Douglas fir	Face	8
	Douglas fir	Edge	8
		End	10
		Face	6
MIL-W-0015154A	White oak	Edge	15
		End	20
		Face	10
MIL-W-2038B	Douglas fir	Edge	10
		End	10
		Face	8

*At end of third cycle of the 12-day test.

Use of 12-Day Test in Adhesive Development

Paralleling the use of the 12-day test for process control is its use for adhesive development research. Much needs to be learned about the behavior of various adhesives on different species. White oak is a good example of a wood which requires special consideration in order to produce good bonds. Much exploration remains to be done on the inter-relationship of various factors such as effect of surfacing, spread, open and closed assembly time, pressure, and minimum curing conditions for flat and curved work. Some investigations have been made on these, but more data are needed. It has been found that some brands of adhesives will not perform well on white oak unless a definite closed assembly time is allowed. Many other influences on glue line quality are in need of study and the 12-day test is playing a useful part in this work.

The past few years have seen the increased use of cyclical exposure tests for pre-determining adhesive durability and the shortening of the test from 180 days to 12 days. Studies are underway which will reduce this test period. Until the quicker tests become available, the 12-day test will continue to provide a valuable tool in adhesive development and laminating quality control.

References

1. Joint Army–Navy Specification JAN-A-397—Adhesive, Thermosetting-resin, Room-Temperature and Intermediate-Temperature Setting, Waterproof (Phenolic, Resorcinol and Melamine Base) (For Wood) dated 20 September 1946.
2. Joint Army–Navy Specification JAN-A-397, Amendment 1 dated 28 October 1948.
3. Military Specification MIL-A-397A—Adhesives, Room-Temperature and Intermediate-Temperature Setting Resin (Phenol, Resorcinol, and Melamine Base) dated 6 April 1951.
4. Military Specification MIL-O-15154(SHIPS) Oak, White, Laminated (For Ship and Boat Use) dated 15 August 1950.
5. Military Specification MIL-W-15154A—Wood, White oak, Laminated (For Ship and Boat Use) dated 9 August 1951.
6. Tentative Method of test for Integrity of Glue Joints in Laminated Wood Products for Exterior

Service, ASTM D-1101-50T American Society for Testing Materials, 1950.
7. Military Specification MIL-F-2038—Fir, Douglas, Laminated (For Ship Use) dated 21 February 1950.
8. Military Specification MIL-A-397B—Adhesive, Room-Temperature and Intermediate-Temperature Setting Resin (Phenol, Resorcinol, and Melamine Base) dated 3 February 1953.
9. Interim Military Specification MIL-W-17445 (SHIPS)—Wood, Pressure-Treateed Oak, Laminated (For Ship and Boat Use) dated 22 December 1952.
10. Military Specification MIL-D-16285B(SHIPS) Decking, Teak–Douglas fir, Laminated (For Ship Use) dated 11 May 1953.
11. Military Specification MIL-W-0015154B(SHIPS) Wood Laminates, White oak (For Ship and Boat Use) dated 10 August 1953.
12. Military Specification MIL-W-2038B(SHIPS) Wood Laminated, Douglas fir (For Ship and Boat Use) dated 7 July 1953.

Dust-Hazard Control in Woodworking Plants

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Relative danger of dust-hazard in woodworking plants is explained, and methods for keeping plants free of the dust-hazard are given. Methods for minimizing the effects of explosions should they occur are also given.

DUST HAS BEEN a hazard in industry since man first engaged in mining, milling, woodworking, or any of the numerous occupations in which finely divided material is produced or handled. Dust can be a health hazard, a fire hazard, an explosion hazard, or just a common nuisance that obscures the vision, mars the finish on varnished surfaces, or stimulates that domestic activity known as spring and fall house cleaning.

In this paper particular attention will be given to the dust-explosion hazard which continues taking a heavy toll of life and property year after year. It has been estimated that the hazard exists in more than 30,000 industrial plants in the United States alone, and a tabulation of all the losses attributable to dust explosions in factories in this country shows that more than 600 lives have been lost, and approximately $90,000,000 worth of property has been destroyed.

With very few exceptions, any dust that will burn or oxidize readily and is fine enough and dry enough to form a cloud in air will explode if the concentration is within certain limits and a source of ignition hot enough to ignite it is present.

There is no particular reason to single out any one industry in discussing dust-explosion hazards, but since the members of this society are presumably interested in wood special attention will be called to losses that have occurred in woodworking plants, and special emphasis will be placed on the flammable properties and the explosive characteristics of wood dust in discussing methods that have been developed for the control of dust explosions.

Losses in Woodworking Plants

Although losses caused by dust explosions in woodworking plants have not been as heavy as those in some other industries, more than 125 reports of explosions of wood dust, wood flour, sawdust, and bark dust are available on which to base a study of this particular phase of the hazard. In this group of explosions 37 lives were lost, 156 persons were injured, and the property damage was more than $7,000,000.

Many of the explosions reported occurred in shavings vaults, especially those in which the fine dust is blown into the vault with the shavings. Others have occurred in or around boiler settings in which wood waste is used as fuel or in burners to which scrap, sawdust, etc., are blown or conveyed for disposal. These are the most likely spots in which to look for explosion hazards, but changes in the industrial field, both in manufacturing processes and in the utilization of by-products, have created hazards in many plants where they did not previously exist and at many locations in a plant where dust was not previously present. In the woodworking industry larger scale operations creating greater quantities of dust from saws, planers, and sanders have increased the possible hazards, and the demand for wood flour has induced many operators to reduce their scrap to powdered form. The utilization of chips, shavings, and scrap in the manufacture of by-products and the use of wood flour in the production of many different materials or varieties of products such as plastics, paints, wallpaper, molded articles, etc., have increased the hazard because of the more extensive transporting and handling processes.

Laboratory Tests

Tests made with a number of wood dusts and several samples of bark dust have indicated that wood dusts as a group are just as hazardous and perhaps more hazardous than the cereal dusts, and apparently one wood dust is just about as hazardous as another. Some investigators have reported exceptionally low ignition temperatures for wood in solid form, wood dust in static layers, and wood dust in suspension as a cloud.

C. R. Brown, in his dissertation on the Determination of the Ignition Temperatures of Solid Materials (1934) reports ignition of cedar, pine, and oak shavings at temperatures ranging from 192° to 220° C. (378° to 428° F.) and cites comparable figures obtained by other investigators with pine and oak sawdust.

The Underwriters Laboratories report two ignitions of wood that had been exposed to temperatures of 190°–212° F. for a long period of time, and there are a number of instances where wood in contact with steam pipes long enough to produce some carbonization has ignited. Similar conditions prevail when wood dust settles on steam pipes, electric lamps, or other heated surfaces and remains there for a long time.

In the usual method of testing in which a layer of relatively fresh dust is placed on a heated surface or in a container within a heated enclosure and the temperature is gradually increased until ignition occurs, most of the wood dusts ignite at temperatures ranging from 523° to 633° F. Although the ignition temperatures of the coniferous wood-dust samples (592° to 633° F.) are slightly higher than those for the broad-leaf woods (523° to 592° F.) the range for both groups is quite limited and of no par-

ticular significance. The ignition temperatures of the bark dusts tested were generally lower than those for either type of wood dust.

The temperature required for ignition of a dust cloud is usually considerably higher than the temperature at which a static layer of the dust will ignite. For example, wood flour that can be ignited as a layer of static dust at 530° F. may require a source of ignition of around 800° F. to start combustion and flame propagation in a cloud of the dust in air. Similarly, birch-bark dust that will ignite as a layer at 482° F. requires a temperature of about 842° F. for ignition when it is in the form of a cloud. While it can be stated generally that the ignition temperatures of clouds of wood dust range from 800° to 900° F., it is well to keep in mind the lower figures for ignition of static dust (approx. 500° F.) because explosions are frequently initiated by the burning of dust deposits that were ignited by the heated surfaces on which they accumulated.

The operators of plants where dust-explosion hazards exist often request information on the lower explosive limit or the minimum concentration of dust in air through which flame will propagate when a source of ignition is introduced. For wood dust the generally accepted figure is 0.05 to 0.06 oz. per cu. ft., but ignition of Douglas fir bark dust was obtained in laboratory tests at a concentration of 0.03 oz. per cu. ft. It should be remembered that many factors affect the explosibility of dust, and the minimum concentration at which an explosion can occur will depend, not only on the amount of dust, but also on the particle size, the shape of the particle, the uniformity of particle size, the uniformity of dispersion, and the moisture content or other conditions that may affect the dispersability. Ordinarily, if the dust is dry enough to be dispersed as a cloud, the moisture content has little or no effect on the explosibility other than to increase the ignition temperature. As the moisture content increases, higher temperatures in the source of ignition are required to initiate combustion of the dust particles.

A number of articles containing information on wood-dust explosions have been published from time to time, and the careful reader may have noticed that the explosion test data differ considerably. Various investigators have used different methods or conducted their tests under different conditions.

In 1935 Edwards and Leinbach, of the U. S. Department of Agriculture, reported the results of tests to determine the explosion pressures following the ignition of clouds of different dusts, including a number of wood and bark dusts.[2] Under the conditions existing at the time these tests were made ignitions of dust clouds of wood and bark at a concentration of 500 mg. per liter (0.5 oz. per cu. ft.) produced pressures ranging from 36 to 44 lbs. per sq. in. A sample of cork dust used in these tests produced a maximum pressure of 40 lbs. per sq. in.

With improved testing equipment at the Bureau of Mines laboratories in which dust clouds can now be more uniformly dispersed than was previously possible, pressure readings about twice those reported by Edwards and Leinbach have been recorded. For example, samples of Douglas fir bark dust, wood flour (presumably pine), birch-bark dust, and a sample of wood-fiber similar to but not directly comparable with the samples mentioned above produced explosion pressures of 60, 62, 70, and 85 lbs. per sq. in., respectively, when tested at a concentration of 0.5 oz. per cu. ft. A sample of cork dust believed to be directly comparable with the cork dust used by Edwards and Leinbach produced 83 lbs. per sq. in. pressure when tested by the improved method at a concentration of 0.5 oz. per cu. ft. As further improvements are made in laboratory equipment and testing methods, it seeems quite likely that still higher pressure readings may be obtained.

For practical purposes, it makes little difference to the plant owner or operator whether the dust that creates an explosion hazard in his plant is capable of producing 36 or 85 lbs. per sq. in. pressure, because the pressure that might be exerted on building walls, floors, or ceilings even at the lower figure would be more than 2½ tons per sq. ft., and no ordinary building is designed to withstand such pressure. Obviously, the thing to do is to eliminate or reduce the hazard by taking all possible precautions to prevent dust ignitions and then provide some form of protection that will minimize the effects of an explosion, if one should occur, by limiting the possibility of propagation or by providing for the release of pressure before it becomes high enough to seriously damage equipment or cause structural damage to the building.

Explosion Prevention and Protection

As information on the explosibility of different types of dust was made available by laboratory investigators, the operators of industrial plants recognized the need for a practical interpretation of the data that would enable them to obtain the desired protection against the dust-explosion hazard. Through the National Fire Protection Association and with the assistance of several Government departments the Dust Explosion Hazards Committee was organized to develop means of preventing dust explosions in industries producing or handling combustible or explosive dusts. This committee, composed of representatives of different industries, insurance organizations, governmental establishments, and safety groups, has undertaken the preparation of codes or standards containing suggestions and recommendations for the practical application of the technical and scientific information on the phenomena and behavior of dust explosions that has been obtained through research and experiments. Seventeen such codes for different types of industry, including a Code for the Prevention of Dust Explosions in Woodworking Plants and a Code for the Prevention of Dust Explosions in Wood Flour Manufacturing Establishments, are now available.

It is not necessary to recite here in detail the provisions of the different codes, because they are available in printed form through the offices of the National Fire Protection Association, the National Board of Fire Underwriters, and the American Standards Association. However, a review of some of the fundamental principles of dust-explosion prevention and a discussion of some of the more recently developed methods of providing protection against the hazard, particularly those that may have special application in woodworking plants, might be helpful.

In view of the flammable nature of the contents of woodworking plants, it is only natural that those who prepared the dust-explosion-prevention codes recommended that the buildings be of fire-resistive or noncombustible construction, but there is another thought involved in this recommendation. Fortunately, methods of reducing the fire hazard frequently serve also to control the dust-explosion hazard. In any plant where such hazards exist cleanliness is of the utmost importance, and in fire-resistive or non-combustible construction the rough surfaces and ledges or lodging places for dust commonly found in light frame construction can be more readily eliminated. Greater cleanliness and better housekeeping can be more easily maintained in buildings of the fire-resistive type with smooth-finish walls and floors.

[2] Edwards, P. W., and Leinbach, L. R., Explosibility of Agricultural and Other Dusts as Indicated by Maximum Pressures and Rates of Pressure Rise: U. S. Department of Agriculture Bull. 490

Dust dispersion at points of production should be carefully controlled. Special emphasis has been placed recently on the physiological significance of dust, and again fortunately methods of controlling dust to eliminate health hazards, respiratory diseases, systematic poisoning, and skin diseases will also serve to control the dust-explosion hazard. Removal of dust at the point of origin by exhaust ventilation or other effective means will prevent the formation of explosive dust clouds or accumulations of dust in the operating area where sources of ignition are usually present and drafts or concussions may throw static dust into suspension.

To apply exhaust ventilation at all points where dust is produced in woodworking plants would be difficult and impracticable; some dust escapes from even the best designed systems. Where such dust collects on benches or floors, it should be removed without creating dangerous dust clouds. In one plant where vacuum cleaners are normally used an accumulation of dust was being hand brushed from a bench while a sanding machine was in operation. The motor operating this machine had been repaired the day before. Apparently, it was defective and produced a spark that ignited the dust cloud. The resulting explosion spread through the room, and the concussion was severe enough to shatter all windows in that part of the building.

This experience in a normally well kept and carefully operated plant emphasizes another important step that should be taken to prevent explosions —the elimination of all possible sources of ignition—and also calls attention to a means of providing protection against explosions that should be universally adopted wherever the hazard exists, namely, segregation of dangerous areas.

All electrical equipment in plants where explosive dusts are produced or handled should be of the type designed and approved for use in such places and should be installed in accordance with the requirements of the authority having jurisdiction in the enforcement of standards covering safe operating practices. It is evident from even a casual perusal of the data on the flammable and explosive characteristics of wood dust that smoking and any use of open flames should be prohibited in areas where such dust may be present. Too many operators in the rush of making urgent or emergency repairs to equipment have failed to realize the danger attending the use of cutting and welding torches in dusty areas. Before such equipment is brought into the area all machines should be shut down, and all dust accumulations carefully removed. If possible, the damaged equipment should be removed and the repairs made elsewhere.

Segregation of hazardous areas can prevent explosions from reaching destructive proportions and disrupting the entire production schedule of a plant. Sometimes individual machines can be segregated; this procedure is followed in some industries where the hazard is extremely great. In woodworking plants where operations are more frequently in series than in batch lots sections of the building can be separated from each other by fire walls and all openings between sections or floors eliminated. In this way any explosions that may occur can be limited or restricted to comparatively small areas.

Venting or the release of explosion pressure before it becomes destructively high is a form of explosion protection that is receiving increased attention. Experience has taught us that sometimes when enough windows are blown out or a light roof is blown off by an explosion the pressure is released before the building is structurally damaged or equipment wrecked. On the basis of this principle, attention has been given to the design of explosion vents for both buildings and equipment. Considerable experimental work has already been done, but it is difficult to prescribe any set rules or formulae for the design and installation of such vents because of the many factors involved. Different types of buildings, as well as equipment, differ in strength or resistance to explosion pressure. Different dusts produce different maximum pressures and have different rates of pressure rise. The location and number of vents provided, the volume of the space to be vented, and the ratio of vent area to volume are some of the factors that must be considered in designing vents to release an explosion before the pressure reaches some predetermined point representing the expected or known resistance of the building or enclosure. Any recommendations for venting, unless based on specific conditions, must be quite general, but as a guide to anyone interested in providing this form of protection it is suggested that rooms and buildings of woodworking plants be equipped with vents in the ratio of 1 sq. ft. for each 80 cu. ft. of volume. Vents may be windows with top hinged sash, light, easily shattered or swinging wall panels, skylights or light roof panels that will be easily lifted by explosion pressure, or some of the special types of ventilators that are designed to open wide and function as explosion vents under pressure. No point of the room, bin, vault, or equipment vented in the ratio given should be farther from a vent than the least dimension of the enclosure.

The use of controlled atmospheres for preventing dust explosions is becoming more general because it is known that, with few exceptions, dust cannot ignite or explode in atmospheres containing too little oxygen to support combustion. Laboratory tests have shown that ignitions of wood flour or dust can usually be prevented by reducing the oxygen content within the enclosure containing the dust to about 14 percent. This reduction can be accomplished by introducing into the air within the enclosure, which normally contains about 21 percent oxygen, proper quantities of carbon dioxide, nitrogen, helium, or other so-called inert gases. This method of preventing dust explosions, of course, can be used only in closed systems, because it is not feasible to reduce the oxygen percentage of working areas or enclosures that employees must enter to perform their duties.

Although information on the causes and behavior of dust explosions is far from complete, experiments and experience have demonstrated that most dust explosions can be prevented. Operators of all plants where the hazard exists are urged to adopt the recommendations incorporated in the different codes and direct their personal attention toward the elimination of dangerous conditions. In this way it is hoped that the large number of explosions in the woodworking industry and the corresponding heavy loss of life and property can be reduced.

Rapid Specific Gravity Determinations

J. FRANK HEINRICHS

Physical Science Aid, Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

Improved method for obtaining specific gravity and volumetric data speeds process and increases accuracy and reliability.

A NEW IMPROVEMENT in the technique for obtaining specific gravity and volumetric shrinkage data, developed at the U. S. Forest Products Laboratory, not only enables observations to be made more rapidly, but also has considerably increased the accuracy and reliability of the results.

Since a good estimate of the strength of a piece of wood may be obtained from its specific gravity, the quality of a sample of wood is determined from its specific gravity and shrinkage properties. In the normal course of investigations at the Laboratory, several thousands of these determinations are made. In each determination, the volume of the wood sample must be known.

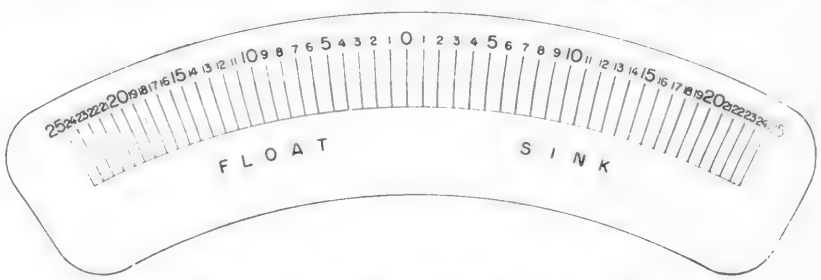
The general method of determining the volume of a piece of wood, which is often of irregular form, is as follows: The specimen is first weighed in air and then weighed when submerged in water. If the specimen has a tendency to float, the volume (in cubic centimeters) is obtained from the sum of the two weights (in grams); if, on the other hand, the specimen tends to sink, its volume is obtained from the difference between its weight in air and its weight when submerged in water.

With a new direct-reading balance and other improvements in technique, more than three times as many volume determinations of wood samples can be made per hour as could be made previously.

A Toledo balance has been adapted in such a way as to give a zero reading at a central point on the scale, instead of at the left end, and to permit a reading of plus or minus 25 grams to be made on either side of the midpoint. The scale is graduated to read to the nearest 0.05 gram. For weights in excess of those indicated on the scale, the balance bar has been slotted and a rider provided that compensates for a gain or loss in weight up to 125 grams. For the rare case when additional weights are needed, they may be added to the balance pan. The new balance comes to rest in a matter of a few seconds, so that the period during which the specimen is submerged is considerably reduced and the readings are indicated directly in such a manner that there is no confusion as to whether the test specimen is a "sinker" or a "floater."

Another feature of the improved method is that the basket in which the submerged specimen is suspended has been completely redesigned so that it can be operated rapidly and has the capacity to hold securely test specimens with a large range in size.

Balance and equipment for determining the specific gravity of wood, showing the basket used for submerging specimens to obtain their weight in water.



Scale used on improved balance for rapid specific gravity determinations.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

A Special FPRS Feature

Around the World in Forest Products Research and Development

Guest Editor, G. M. HUNT

TIMBER GROWING and harvesting, and the processing of the products of the forest, furnish work for millions of people in the fortunate countries that have forests of industrial size and character. For many countries, the exportation of forest products constitutes an item of major importance in maintaining their international trade balance. A century or two ago, when the world population was much smaller and the forested areas much larger than today, timber in many places was largely a nuisance because it occupied land that was wanted for farming. In such places, wood had no inherent value. Its cost to the user depended only upon the labor and transportation invested in it. Now, not only does standing timber have value because of the much more limited supply and increased demand, but all the costs of labor, transportation, and distribution have increased so enormously that wood is no longer a material to be wasted with impunity. Furthermore, wood-exporting countries find it to their economic advantage to export wood in the form of manufactured products rather than in the raw state such as pulpwood, mine timbers and sawlogs. Thus wood and wood processing have gradually assumed a new importance and presented new opportunities in the timber-producing countries and herein lies the need for local forest products research and development. An additional stimulating factor is the increasing competition that wood faces from metals, plastics and other new developments from research in other fields. Expanded research and development in wood products is the best defense of the wood industry against their encroachment.

Organized forest products research is of relatively recent origin although the earliest developments in wood use began in prehistoric times. In the intervening centuries there have been innumerable instances of research or development work on wood or wood products at universities, by manufacturers, or by individuals, which have greatly advanced our knowledge of how to use wood more efficiently, more effectively, and for a greater variety of purposes. The forest products laboratory as we know it today, however, in which groups of men and women pool their different trainings and skills and, with special facilities, concentrate their energies on wood problems, appears to have had its start in Madison in 1910. Research in forest products had begun on a limited scale before this in the United States, India and other countries, but it was usually subordinated to and in connection with other research. Soon after 1910, specialized forest products laboratories began to operate in India and Canada, to be followed later by similar laboratories in Australia, South Africa, England, and many other countries. The number is still growing. Forest products research and development has thus received world-wide recognition as a necessity for every important wood-using and wood-exporting country.

The Forest Products Research Society was organized to stimulate interest in forest products research and development and to assist in the dissemination of information on all phases of forest products production, distribution and utilization. It was planned as an international organization, open to interested individuals in all countries. Because of differences in language and difficulties with foreign exchange, however, its membership is confined largely to the United States and Canada. Nevertheless, some 30 other countries are represented in its membership. It is hoped that this number will increase, as well as the number of members in each country.

The concentration of membership in Canada and the United States tends to focus the attention of the Society and its publications on the progress and problems of these countries to the exclusion of what is going on in the rest of the world. Such provincialism, if continued, would deprive the Society membership of much interesting information about forest products problems in other countries, the institutions and personnel working upon them, and the progress being made toward their solution. A proper knowledge and appreciation of these things should be helpful as well as interesting to all members of the Society.

For these reasons, the Journal of the Forest Products Research Society is inaugurating a new department with this issue, to be devoted to news and information about forest products from all over the world outside of Canada and the United States. It will provide descriptions of the institutions devoted to wood research in these other countries, their problems, their research programs, and their accomplishments. It will also include news and discussion relating to these subjects and, it is hoped, carry contributed articles of technical interest and importance by workers in the various countries. Wood research is world wide. F.P.R.S. members deserve world-wide information. The function of this department of the Journal will be to provide it with the cooperation of the workers in the respective countries, upon whom we rely for appropriate technical articles, news notes, and letters.

Austria Has a New Forest Products Laboratory

On October 22, 1953 a new forest products laboratory was formally opened in Vienna with imposing dedication ceremonies. Representatives of the Austrian Government, the Austrian Wood Industries, the U. S. Government, the Food and Agriculture Organization of the United Nations, and forest products research institutions in Germany and Switzerland were among those participating in the dedication. Forests cover more than one-third of Austria and, together with the wood industries dependent upon them, fur-

The Austrian Forest Products Laboratory as it neared completion in Vienna. It is located on the grounds of the former Government Arsenal, which is being converted into a research center for various investigations. (Photo by Serentschy)

nish employment to some 200,000 persons. Thus they are of great economic importance to the nation. Wood and wood products constitute one of Austria's principal items of export and one of its chief sources of foreign exchange. Austria's forests are not inexhaustible, however, and the annual cut of timber, in the long run, must be limited to what can be produced on a sustained yield basis. In fact there has already been too much overcutting, which must be remedied. It is necessary, therefore, to work towards maximum efficiency in all the processes of manufacturing and utilizing the forest crop so that the people and the industries of Austria may derive the greatest possible benefit from their forest assets without diminishing them. Under such circumstances, the need for research and development in wood processing and utilization is obvious.

Before the establishment of the new laboratory, some forest products research, largely fundamental in character, had been done by individual pro-

Active in the Austrian Forest Products Laboratory are, left, Dipl.–Ing. Heinrich Wartburg, Administrative Director of the Laboratory; center, Hofrat Dipl.–Ing. Felix Feest, President of the Austrian Society for Wood Research; and right, Prof. Dr. Josef Kisser, Scientific Director of the Laboratory.

fessors in universities and schools, some by private industry, and a little by the Forestry Research Institute incidental to its main job of research in silviculture and other aspects of timber growing and management. There had been no centralization of the forest products work. The need for a central institution for forest products research and development has long been recognized by the leaders in forestry and the wood industries, particularly those who are members of the Austrian Wood Research Society (Österreichische Gesellschaft für Holzforschung (ÖGH)). The United States Economic Cooperation Administration to Austria early decided to devote a substantial portion of Marshall Plan aid to the rehabilitation of Austria's forests and the modernization of its forest industries and prepared plans to that effect. In 1949, at the request of the Austrian Government, the Food and Agriculture Organization of the United Nations began a study of the entire forestry problem in the country, which extended into 1953. One of the important developments early in the study was a recommendation urging the establishment of a forest products laboratory. Although the need for such an institution was thus generally recognized, the financial difficulties in the way of its establishment seemed almost insurmountable, for the Austrian economy was still suffering from the aftermath of war and money was exceedingly difficult to obtain. Adequate funds for the complete equipment, staffing, and operation of the laboratory are not yet in sight but, through Marshall Plan funds, contributions from industry through the ÖGH, and a loan from the city of Vienna, an excellent building has been provided on the grounds of the old Government arsenal in Vienna. This area, formerly devoted to the production of munitions of war, is now being developed into a national center for research in various fields. Much valuable equipment has been installed in the new laboratory and with a limited number of full-time employees and the part-time services of a number of university research leaders in Vienna, it is gradually getting into operation.

The laboratory building is U-shaped, as shown in the accompanying photograph. It consists in part of an old building remodeled and in part of new construction and has a total usable floor space of about 4,000 square meters on three floors, divided into nearly 100 rooms. Steam for heating and processing is supplied from the central power station on the Arsenal grounds. Electricity and gas are obtained from the Vienna electric and gas systems. Four of the laboratory rooms are to be equipped with humidity and temperature control that can be adjusted to the needs of the work being done in them. The usual laboratory space and equipment are provided for library, photography, business management, chemical studies, dry kiln, wood-treating facilities, woodworking, strength testing, metal shop, and the like. The large room shown at the right in figure 1 has a floor area nearly 18 by 27 meters in size and is open from floor to roof, thus providing space for the construction and testing of large structural elements or housing units.

The ownership and management of the laboratory are vested in the Austrian Society for Wood Research (ÖGH) whose president and general manager is Hofrat Dipl. Ing. Felix Feest. This society is largely supported by the wood industries although its membership includes university research workers, government and private foresters, consultants, and all others interested in wood research who care to join and pay the low cost of individual membership. The forest products laboratory is, therefore, essentially industry owned and operated although the government and university researchers are represented in its councils and active in its affairs.

The scientific council of the Society (Wissenschaftlicher Beirat), consists of 50 to 60 men representing industry, science, research, education, forestry, government, and trade. It includes a number of the staff of the new laboratory and a wide variety of other interests. The function of this council is to consider the research problems presented to or recognized by the Society and make recommendations concerning what should be done and what financial support should be given by the Society. The managing board of the Society, consisting of the president, vice president, and 24 members selected to represent science, forestry, woodworking industry, sawmill industry, paper industry and woodworking trades (holzverarbeitende Gewerbe), exercises the overall authority of the Society. During intervals between meetings of this managing board an executive committee of eight acts on all matters that do not require the attention of the full board.

The immediate supervision and direction of the laboratory's research work is under a scientific director (Wissenschaftlicher Leiter) Professor Dr. Josef Kisser of the College of Agriculture and Forestry in Vienna, who will divide his time between the

work of the laboratory and that of his college. The business management and general administration of the laboratory are under a business manager (Geschäftsführer), Kommercialrat Dipl. Ing. Heinrich v. Wartburg, who will spend full time on the work.

The research work of the laboratory will be divided among 7 divisions, each headed by a division chief (Abteilungsleiter), as follows:

I. wood structure and microscopy,
II. wood chemistry and chemical technology,
III. pulp and paper,
IV. wood preservation and mycology,
V. physical and mechanical properties,
strength testing,
VI. wood technology (mechanical technology) subdivided into:
a) wood treating and improving (Holzverformung und Holzveredelung)
b) plywood, fiberboard and chipboard,
c) wood working and end processing (Holzverarbeitung und Endfertigung)
VII. timber construction.

The present heads of these divisions are active in the work of the Wood Research Society and, for the most part, represented on its scientific council. They are thus able to have a direct influence upon the recommendations of the Society with regard to the investigative work that should be undertaken. The division heads and the directors also recognize that numerous problems with which the laboratory will be concerned will require several kinds of skills and cannot properly be handled within any one division. They expect that much teamwork will be required on various investigations between two or more of the several divisions. In this element of teamwork lies the essential superiority of a central institution that can focus many skills on one problem in comparison with an equal number of investigators working separately in widely scattered institutions. United action under intelligent direction makes the most progress and the fewest mistakes.

The research program of the laboratory is expected to consist mainly of applied research and developmental work. Although some fundamental research may also be done, it is expected that such studies will remain primarily in the universities and technical schools. Proposals for research problems to be undertaken will come from members of the laboratory staff, wood-using industries, government representatives, educational institutions, and anyone else interested. The propoals will then be considered by the Scientific Council of the Ö. G. H. which will recommend the projects it believes should be included in the program. Final decision will be made by the managing board of the Society in collaboration with the scientific director of the laboratory and his staff, and will, of course, be influenced by the personnel, the equipment, and the funds available. It will also be possible for individual companies to arrange to have special studies made for them upon payment of the costs and arranging about patent rights. Since this is a private rather than a government institution, it will be in order for it to take out patents on developments that seem to justify this procedure. With good fortune, some of the patents may, in time, bring substantial financial returns to be used in furthering the work of the institution.

The Austrian Wood Research Society, in the past, has published its proceedings and communications in a special section of the "Internationaler Holzmarkt" of Vienna entitled "Mitteilungen der Österreichschen Gesellschaft für Holzforschung." No doubt this medium will continue to be used by the new laboratory, as well as other forms of publication as needed.

One of the important functions of the laboratory will be to serve as a clearing house for information on wood utilization and a source of advice and assistance to the wood industries. The laboratory staff must, of course, keep well informed on the accumulated knowledge of the world about wood and wood processing and adapt this knowledge to the specific problems of Austria through meetings, publications, correspondence, and individual consultation. For this reason, the laboratory will not be able to devote its entire time to research, but must make application of the results of research an important phase of its work. Its personnel must maintain close and friendly relations with all the wood industries of Austria, in order to understand their needs, to search out opportunities for improvement, and to gain the confidence of the industries in the ability of the laboratory to assist them. The success of the laboratory and the technical progress of the Austrian wood industries depend upon close cooperation and mutual understanding between the two groups.

The mailing address of the new institution is "Das Österreichische Holzforschungsinstitut, Wien III, Arsenal, Objekt 212, Austria."

The Timber Dryers' and Preservers' Association of India

This new addition to the list of technical associations concerned with the processing and utilization of wood is unusual in that it covers both wood seasoning and preservative treatment. There is nothing incongruous in this combination, however, for it is often necessary to use both processes in preparing timber to give its best service. Certainly it is desirable for the specialists in each field to know about the other.

The assocation issues a Quarterly News Bulletin, Volume 1, No. 1 of which appeared in July 1953 and listed the names of 67 members. The constitution issued in 1952 provides for 4 classes of members, as follows: professional, commercial, associate and honorary, with the privilege of office holding limited to the professional and commercial members. The stated objectives of the association are to promote the use of seasoned and treated wood for all purposes of construction for which it is suited, to bring into contact producers and consumers of timber and all interested in the use of seasoned and treated timber, to investigate and accumulate knowledge, hold meetings, issue publications, to assist in the establishment and operation of seasoning and wood-preserving plants, to train technicians for plant operation, to educate the public on the need and advantages of using seasoned and treated wood, and to cooperate with other organizations in the furtherance of these objectives. The association will also prepare technicel standards.

The headquarters of the association will be at the Forest Research Institute, Dehra Dun, U. P. India, for the first five years, after which it may be moved if then found desirable.

It is stated in the first quarterly news bulletin that there are about 12 commercial pressure-treating plants in India of which six use creosote or creosote-petroleum mixtures and six use the water-borne copper-chromium-arsenic preservative known as "Ascu" in India and as "Greensalt" or "Erdalith" in the United States. This preservative was developed by Dr. S. Kamesam in 1933, while a member of the staff of the Indian forest products laboratory, as an improvement of the earlier "Falkamesam" formula developed jointly by himself and Dr. Falck of Germany in 1931. India produces some coal-tar creosote, can produce Ascu from local chemicals with the possible exception of the arsenic, and has other preservatives, including pentachlorophenol and copper naphthenate available. In the past, impregnating cylinders and their equipment

were imported but it is now possible to build both pressure plants and open tank plants of any size or shape in India with a consequent saving in time and cost.

New Laboratory in East Pakistan

Laurence V. Teesdale, research engineer and architect at the U. S. Forest Products Laboratory, Madison, Wis., has returned from an assignment in East Pakistan, where he helped lay out a new forest products laboratory and sawmill at Chittagong, as part of the Point Four Program under the U. S. Foreign Operations Administration. The forestry project is part of an overall plan to develop industries and improve all phases of Pakistan's economy, according to Teesdale.

The new forest products research laboratory, to be built by the provincial government of East Pakistan, will include lumber dry kilns, a wood-preserving plant, a chemical laboratory, a wood-working shop, and equipment for the manufacture of veneer, plywood, fiberboard, and hardboard from local materials. The laboratory will be operated as a branch of the forest service and the director will be Mr. Q. Ghani, Pakistan Divisional Forester, who recently completed a training period at the U. S. Forest Products Laboratory.

The new Laboratory in East Pakistan will work for the modernization of lumber manufacturing methods.

The sawmill will be a government operated production mill and will have a capacity of 15,000 tons of logs (about 5 million bd. ft.) a year. It is planned to enlarge it in time to a capacity of about 40,000 tons (over 13 million bd. ft.). At present, a high percentage of the lumber produced in East Pakistan is by hand sawing methods (whipsawing).

"Industrialization is sorely needed," Teesdale said. "Although it is predominantly agricultural, East Pakistan is so densely populated that there is not much room for expansion of farming. One area of about 500 square miles has 3,000 people to the square mile. In all, there are 46 million people—roughly one-third the population of the United States—in an area the size of Wisconsin, and a part of it is heavily forested."

The principal forest covers 8,500 square miles of hilly border land between Pakistan and Burma. It is a difficult area to harvest, according to Teesdale, because the hills are rugged and extremely steep. Modern logging equipment is being ordered for the woods operations, to replace the elephants and oxen now used.

All the woods are hardwoods, with logs commonly running 3 to 4 feet in diameter. As most of these heavy logs are sinkers, they must be supported by bamboo for the 90-mile float down the Karnapulli river from the cutting area to the sawmill at Chittagong.

The most important species is gurjun, a dense wood that runs about 70 pounds to the cubic foot. Although lumber from this wood has a tendency to fuzz, it can be worked with very sharp tools and is suitable for the manufacture of furniture. The country also produces much bamboo and a pulp and paper mill is under construction which will ultimately produce 100 tons of paper per day from this material.

There are many problems to be solved. For example, the logs can be harvested 12 months of the year, but they can be floated downriver only 6 months of the year, when the water is high. This means many logs have to be stored without protection for 6 months or more, which often results in considerable deterioration from checking, insect attack, and decay. This problem will be partially solved by the use of water storage tanks and will be eliminated in a few years with the completion of a dam that will maintain an adequate water level to float logs to Chittagong all year round. As these and other problems are solved the forests will provide the provincial government of East Pakistan with a considerable source of income.

Finland Studies Veneer Knife Honing

The preparation of a knife for cutting veneer on the lathe involves careful grinding to a fine, straight edge. Usually the knife is ground to a bevel lying between 19° and 21°. After a knife is ground, it must be honed to remove the feather edge. Sometimes honing is also employed to provide a stronger, somewhat blunter edge by changing the bevel at the very tip of the knife—a process sometimes called "face bevelling," or "back bevelling," depending on which side of the knife is honed back. The practice of knife honing is surrounded by a great deal of mumbo-jumbo, none of it based on controlled scientific tests. Recently two Finnish investigators, E. Kivimaa and M. Kovanen*, studied the effect of the "micro-bevel," obtained by closely controlled honing technique, on the quality of the veneer produced in the lathe. Micro-bevels were honed back (1) from the face or ground surface, (2) from the back, and (3) from both sides. Cutting tests on Finnish birch, cut approximately 1/16-inch thick, showed that the bevel angle which they called the "microlip angle", should be 27°, and the length of the honed section, measured from tip back, should be from 0.004 to 0.008 inch. Whether the honing was done from one side or the other, or from both, made little difference. Hand honing without a guide, as ordinarily practiced, did not result in the degree of accuracy required for best results.—H. O. FLEISCHER.

* Vanerisorvin Terien Mikroteroituksesta (Microsharpening of Veneer Lathe Knives). Valtion Teknillinen Tutkimuslaitos, Tiedoitus 126. Helsinki, 1953.

Wood Fuel

The use of wood for fuel throughout the world has far greater importance than is generally realized. Statistics are too incomplete to show the percentage of the world's total wood harvest that is used in some form or other for fuel, but it is believed that more than half of the estimated 60 billion cu. ft. of wood consumed in 1951 was for this purpose.

Perhaps two-thirds of this fuelwood was cut by farmers and others for their own use and does not appear in most statistics. A great deal of wood waste in the form of sawdust, shavings, bark and other residue is used for industrial fuel in the lumber-producing regions, but such use probably accounts for a much smaller percentage of the total wood-fuel consumption of the world than the quantities used for domestic fuel.

Where oil, gas and electricity are readily available at moderate cost for heating and cooking, and the people can afford automatically controlled equipment for using them, their convenience and cleanliness make them attractive and they tend to displace wood and coal. There are large areas of the world, however, where these fuels are unavailable or are too costly for the average family to use, but where wood or charcoal are within their economic reach. Wood and charcoal are used for fuel to some extent in all countries, but their importance for this purpose varies widely in different countries, according to economic conditions.

Abstracts

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiber board and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

FOREST PRODUCTS AND UTILIZATION ABSTRACTS are published quarterly by the Commonwealth Agricultural Bureaux of London, England, as a separate reprint of decimal sections 3, 7, and 8 of Forestry Abstracts, for the facility of those interested chiefly in the field of wood utilization. The abstracts are prepared by the Commonwealth Forestry Bureau, Oxford, England, and the utilization section contains about 1,200 titles and abstracts per year from literature in some 30 languages and covers all aspects of forest utilization from cutting and extraction through marketing, mechanical, and chemical processing to minor forest products. FPRS members interested in obtaining the complete issues of Forest Products and Utilization Abstracts should communicate with the Secretary of the Society.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

Marketing

Sulland, A. Sammenliknende kalkyle over lonnsomheten av slip og kubb, vedtommer og ved av gran. [Calculations on the comparative profitability of timber-length pulpwood, short pulpwood, fuelwood in timber lengths and fuelwood of Spruce.] *Tidsskr. Skogbr.* 61 (4), 1953 (147–52). [Nor.]

The study is concerned primarily with the most profitable disposal of thinnings from young plantations. Figures showing the value obtained (prices for 1952–3) in kroner/tree for trees of d.b.h. 9.1, 11.3 and 15.5 cm. are tabulated and recommendations are made for obtaining the maximum value from combinations of the different assortments. The calculations were based on solid volume, and volumes of short pulpwood and fuelwood were converted from stacked to solid volume for comparison. [Forestry Abstracts, V. 14, No. 4]

Miyoshi, S., and Ogata, Y. [The management of the natural forest of Shii *(Shiia)* and Kashi *(Cyclobalanopsis)* in Miyazaki. (No. 3). The felling and extraction of Shii and Tabu.] *J. Jap. For. Soc.* 34 (2), 1952 (43–5). [Jap.e.]

Costings for felling, trimming, cross-cutting, barking and transport of Shii and Tabu [*Machilus thunbergii*] showed the stumpage values for pulpwood to be 214% above that for charcoal wood. The additional value of such utilization for the natural forest is stressed. [Cf. *For. Abstr.* 13 (No. 3879).] *From author's summary.* [Forestry Abstracts, V. 14, No. 4]

Yearbook of forest products statistics 1952. FAO, Rome. 1952. pp. 172. [E. F. Span.]

Contains new information for 1951 and revised data for 1950, for more than 100 countries.

European timber trends and prospects: a study prepared jointly by the secretariats of the Food and Agriculture Organization of the United Nations and the United Nations Economic Commission for Europe. FAO, Geneva. 1953. pp. 315. Price $3.50 or 25*s*.

Deals with production, consumption, international trade, and general trends. There are 214 tables of statistics. [Forestry Abstracts, Vo. 14, No. 4]

European timber statistics 1913–1950. FAO, Geneva. 1953. pp. 30 + 48 tbls. [E. F.] Price $1.75, or 12*s*. 6*d*.

For the first time an attempt has been made to arrive at figures for trade and production in wood and wood products for every European country and to bring them together in convenient form for reference. The war years 1914–19 and 1939–45 have been excluded for lack of adequate statistical data. The volume is divided into 3 sets of tables, dealing respectively with production, trade, and consumption. Within each section a distinction has been made between the various wood products according to the degree of processing to which they have been subjected. [Forestry Abstracts, V. 14, No. 4]

Properties of Wood

Nolde, I. von. Die wichtigsten Holzarten des Monsunwaldes Kolumbiens. [The most important specie of Colombia's monsoon forests.] *Z. Weltforstwirt.* 16 (1–2), 1953 (36–7; 72–3). [G.]

Describes the tree and the wood, with notes on distribution, trade names and uses, of *Tecoma peroba, Vitex columbiensis, Pithecellobium dulce, Prosopis juliflora, Anacardium excelsum, Cariniana pyriformis, Castilloa elastica, Cedrela* sp.; *Centrolobium* sp., *Chlorophora tinctoria, Copaifera officinalis, Cordia alliodora, Dialium divaricatum, Lecythis ollaria, L. curranii, Myroxylon toluiferum, Protium guianense, Swietenia macrophylla* and *Licania arborea.* [Forestry Abstracts, V. 14, No. 4]

Gerry, E. Information leaflet. Foreign woods. *Rep. U. S. For. Prod. Lab., Madison* Nos. *R*1920, 1952, pp. 9, 35 refs.; *R*1921, 1952, pp. 5, 12 refs.; *R*1924, 1952, pp. 5, 15 refs. P.R.

*(R*1920): Apitong, Bagac, Eng, Gurjun, Yang (*Dipterocarpus* spp.).

*(R*1921): Albarço, Bacú *(Cariniana pyriformis).*

*(R*1924): Imbuia, Embuia or 'Brazilian Walnut' *(Phoebe porosa).*

Levy, J. F. A method of embedding brittle specimens of wood [in polyvinyl lactophenol] for sectioning. *Nature, Lond.* 171 (4361), 1953 (984). [Forestry Abstracts, V. 14, No. 4]

Kisser, J., and Jünger, E. Mikroskopiche Zellwanddeformierungen von Holzelementen bei der Schnittanfertigung. [Microscopic cell-wall deformation of wood elements occurring during the cutting of sections.] *Repr.* from *Mikroskopie, Wien* 7(7/8), 1952 (272–83). 16 refs. [G.g.e.] X. [Forestry Abstracts. V. 14, No. 4]

Bruyne, A. S. de. Wood structure and age. *Proc. ned. Akad. Wet. 55C* (3), 1952 (282–6 + 4 photos). 6 refs. [E.e.] [Laboratorium voor Algemene Plantkunde, Wageningen.] O.R.S.

Stresses the need to base a description of wood on discs or wedge-shaped

blocks including the centre of the tree and large enough to ensure the presence of mature wood. The main description should be of the mature stage but immature and transitional stages should also be briefly described. Variations in ray structure of *Pterospermum diversifolium* with distance from the core are illustrated with photomicrographs. The age of the wood for each stage, where growth rings are clearly demarcated, is best indicated by the number of growth rings, but for comparison with wood grown in different conditions or samples where growth rings are indistinct, distance from the core in cm. should also be given. Ontogenetic development can be used in identification and an example is given showing that *P. diversifolium* and *P. javanicum* (closely related species), can be distinguished by the pore diameter at different stages of development in ray structure. [Forestry Abstracts, V. 14, No. 4]

Preston, R. D. The molecular architecture of plant cell walls. Chapman & Hall, London. 1952. pp. xii + 211 + 32 photos. P.R.

Includes sections on: form of the plant cell; chemical nature of the constituents of the secondary wall; physical methods for the investigation of structure in plant cell walls; structural features of cellulose and the spatial relationships of the incrusting substances; wall structure in thick cell walls; structural variations in homologous cells; primary wall of growing cells, and mechanisms of orientation and growth. [Forestry Abstracts, V. 14, No. 4]

Volz, G. Elektronenmikroskopische Untersuchungen uber die Porengrossen pflanzlicher Zellwande. [Research with the electron microscope into the pore size of plant cell walls.] *Repr. from Mikroskopie, Wien* 7(7/8), 1952 (251–66). 48 refs. [G.g.c.] X.

Examination of very thin sections under the electron microscope reveals holes and thin areas in the cell wall that are invisible under the ordinary microscope. Specimens of the phloem of a number of angiosperms and gymnosperms were examined, and the number, arrangement, and size of the holes and thin areas were clearly seen. It was possible to distinguish clearly between the diameter of the holes in the longitudinal walls (sieve fields) and in the transverse walls (sieve plates), and between the sieve tubes of early and late phloem. In the gymnosperms, and also in some angiosperms, a fine membrane closes the holes of the sieve pits and the sieve fields. The physiological significance of this discovery is discussed. Outside the sieve fields proper are to be found plasmodesma holes, invisible under the ordinary microscope, of a diameter of 0·02μ, displaying 'closed construction'. [Forestry Abstracts, V. 14, No. 4]

Kisser, J., and Wittmann, W. Fluoreszenzmikroskopische Untersuchugen an verholzten Zellwanden. [The study of lignified cell walls by fluorescene microscopy.] *Repr.* from *Mikrochemie, Wien* 36/37, 1951 (1134–45). 23 refs. [G.g.f.c.]. X.

A study was made to determine whether the primary blue fluorescence of the lignified cell wall could be used as a test reaction for lignification. It was found, however, that the blue fluorescene could be made to disappear by exhaustive extraction with hot water and also by treatment with a weak oxidizing agent, though the lignin content of the membrance was little changed. It is probable that the blue fluorescence is conditioned by the water-soluble lignins present. [Forestry Abstracts, V. 14, No. 4.]

Paclt, J. Kernbildung der Buche (*Fagus silvatica* L.) [Heartwood formation in Beech.] *Phytopath. Z.* 20 (3), 1953 (255–9). 9 refs. [G.] [Institut für Holzforschung, Bratislava.] O.R.S.

The author discusses literatures on heartwood formation in Beech and restates his theory that conditions for its formation are abnormal penetration of air through two wound centres, one in the branches and the other in or near the root system. The progress of heartwood formation is as follows: original impulse (generally non-specific: lack of light in the stand, frost, mechanical damage); specific impulse, wounding; localization—crown and root; abnormal diffusion of air through the stem, necrosis of wound; and formation of tyloses and oxidation of tannin complexes as the defence mechanism of the tree. Photographs are given showing the presence of false heartwood in Beech roots. [Forestry Abstracts, V. 14, No. 4.]

Limaye, V. D. Standard terminology for describing timbers. *Indian For.* 79 (2), 1953 (77–86).

Taking Teak as the standard, the physical and mechanical properties of some 100 other Indian timbers are compared with it by index figures already published [cf. *For. Abstr.* 13 (No. 2419)]. The species considered are classified according to their weight, strength as beams, hardness, impact resistance, and stability. Five species are described as an example of the use of the proposed terminology: e.g. *'Cedrus deodara* is a moderately heavy (35), moderately strong (80), moderately hard (70), steady (85) and straight-grained timber'. [Forestry Abstracts, V. 14, No. 4.]

Kenworthy, R. W. and Burnam, T. D. The absorption coefficients of Fir plywood panels. *Journal of the Acoustical Society of America, Lancaster, Pa.* 23 (5), 1951 (531–2). 1 ref. P.O.

The absorption coefficients of flat, splayed, and cylindrical panel assemblies made from ¼-in. 3-ply wood have been measured by the reverberation-chamber method under 3 different conditions. All panels have greater absorption at the lower frequencies (128 and 256) than at higher frequencies. The effective absorption of each type can be increased by using a ½ in. kapok felt in combination with it, either mounted on the wall behind the panel or spot-cemented to the plywood. Each type of panel has desirable characteristics under certain conditions. The absorption of all types indicates that such panels are important acoustical materials in the lower frequency range. *Authors' Summary.* [Forestry Abstracts, V. 14, No. 4]

Millett, R. S. Variation in moisture content in wood exposed to indoor conditions. *Timber of Canada* 13 (7), 1953 (21–3, 34, 36).

Seasoned samples from 6 softwood and 5 hardwood species, after storage to moisture equilibrium indoors, were placed in positions known to have the lowest relative humidity in winter and the highest in summer in the Forest Products Laboratory, Ottawa, and weighed at weekly intervals over 2 years. The highest, lowest and mean of monthly average moisture content, and equilibrium m.c. by species, are shown in graphs. With the exception of Basswood, which gave lower m.c. values than the other species, there was little difference between individual species and between hardwoods and softwoods; Sugar Maple and White Spruce showed the greatest seasonal variation in m.c. (5·8 and 5·7% respectively) and Basswood and Red Pine the least (4·4 and 5·1%). Summer m.c. ranged from 10·2% for White Spruce to 9·4% for Yellow Birch and 7·9% for Basswood, and winter m.c. from 4·6% for Balsam Fir and Red Pine to 4·0% for Beech and 3·5% for Basswood. The average yearly m.c. of all species excluding Basswood was 7·3% and drying to a m.c. of 6% (5% for Basswood) is recommended for wood for general indoor use in heated buildings. Tabulated figures are given showing the maximum seasonal variations in m.c. of the species studied, tangential shrinkage when drying from green to oven-dry, and their calculated change in dimension during maximum variation in m.c. [Forestry Abstracts, V. 14, No. 4]

Schwartz, W. Beitrage zur Kenntnis des Holzes als Werkstoff, III. Untersuchungen uber die Beeinflussung der Quellung des Holzes durch Impragnierung.) [Contributions to knowledge of wood as an industrial material, III. The effects of impregnation on the swelling of wood.] *Angew. Bot.* 26 (5), 1952 (228–39). 4 figs. [G.g.] E.M.B.

Thin sections of Birch, Beech, Gaboon and Spruce were tested for swelling in a humid atmosphere after treatment with various chemical compounds. Swelling increased after treatment with LiCl and Na_2CO_3 solutions but was reduced by $CaCl_2$ and $Ca(HCO_3)_2$. Simple phenol derivatives have a varying effect on swelling, but the introduction of alkyl residues or Cl increases the inhibition of swelling. Rinsing in water after treatment with phenyl salicylate, guaiacol, xylenol, cinnamic acid and phenol carboxylic acid shows that the inhibition of swelling is reduced by washing, but is not eliminated. When pressure was applied during impregnation with tannin, phenol, cresol, guaiacol, xylenol, thymol, trichlorophenol and other compounds, the protective effect was increased. Best results of this kind were obtained with *m*-xylenol, menthol, guaiacol, thymol, *o*-cresol, *p*-chlorophenol, trichlorophenol, and *p*-cresol. Tests with sections from which (*a*) lignin, and (*b*) cellulose had been removed showed that both the cellulose and the lignin are involved in the swelling process. [Forestry Abstracts, V. 4, No. 4]

Meredith, R. [Editor]. Mechanical properties of wood and paper. North-Holland Publishing Company, Amsterdam. 1953. pp. 298 + 1 dgm. 8 pp. of refs. [E.] price *Fl.* 25 (£3. 4*s*.).

The work consists of two parts: (I) The mechanical properties of wood and their relation to water, by *W. W. Barkas,* with one chapter by *R. F. S. Hearmon,* contains an introduction (historical, the theory and measurement of elasticity of wood, gels and swelling stresses, anatomical and molecular structure, development of the wood, the model cell, and cell-wall constitution), and chapters on: elastic and plastic properties: hygroscopicity, swelling and shrinking; osmotic pressure and swelling stresses; and plastic swelling and sorption hysteresis. (II) The mechanical properties of paper, by *H. F. Rance.* [Forestry Abstracts, V. 14, No. 4]

Wood Chemistry

Schubert, W. J., Passannante, A., Stevens, G. de, Bier, M., and Nord, F. F. Investigations on lignin and lignification. XIII. Electrophoresis of native and enzymatically liberated lignins. *J. Amer. chem. Soc.* 75 (8), 1953 (1869–73). Many refs. O.R.S.

[Cf. *For. Abstr.* 14 (Nos. 659-60).]

The native lignins of Oak and White Scots Pine were analysed electrophoretically at various stages of purification, and the dependence of their electrophoretic mobility on pH and ionic strength was determined. With purified Oak lignin a symmetrical boundary characteristic of an electrophoretically homogeneous compound was observed, while the Scots Pine lignin presented patterns characteristic of a multicomponent system. Patterns identical with those for native lignin were obtained from enzymatically-liberated lignin of Scots Pine. Maple and cork lignins gave patterns characteristic of a homogeneous compound, and bagasse native lignin showed only slight inhomogeneity. [Forestry Abstracts, V. 14, No. 4]

Kratzl, K., and Tschamler, H. Ultrarotspektren von Holz und unloslichen Ligninen. [Infra-red spectra of wood and insoluble lignins.] *Monatshefte für Chemie, Wien* 83 (3), 1952 (786–91). 9 refs. [G.g.] D.S.I.R.

The infra-red spectra of different insoluble and soluble lignins, of a dry residue of an aqueous wood extract, and of Spruce wood, show absorption bands at 6·3 and 6·6μ, characteristic of the C=C frequencies of an aromatic compound. The infra-red spectrum of Spruce wood is very similar to that of 6-tritylcellulose between 6·2 and 6·8μ, but differs much from that of methylcellulose. [Forestry Abstracts, V. 14, No. 4]

Zenczak, P. Extraction of lignin from wood with triethylene glycol. *Northw. Sci.* 26 (4), 1952 (145–51). 4 refs. L.S.

Wood chips, bark, or sawdust is heated 1–4 hours at 120–140° C. with triethyleneglycol containing 0·2–0·4% of a catalyst (metal chloride, dry or aqueous HCl), and triethyleneglycol-lignin is precipitated with water from the filtrate, and then purified by repeated precipitation from dioxane by $(C_2H_5)_2O$. This lignin is soluble in many polar organic solvents, $CHCl_3$, solutions of NaOH and Na_2CO_3, etc. Its methoxyl content is 15·3%. When heated it undergoes self-polymerization. [Forestry Abstracts, V. 14, No. 4]

Grohn, H. Utersuchungen uber den Kohlenhydrat-Lignin-Komplex des Fichtenholzes. I. Übersicht uber den Stand der Forschung. II. Experimenteller Teil. [Investigations on the cellulose/lignin complex of Sprucewood. I. Review of present position of research. II. Experimental part.] *Chemische Technik, Berlin* 3 (8; 10), 1951 (240–4; 299–302). 37 refs. [G.g.] L.S.

The general survey (Part I) includes, as a special section, an account of work done in the U.S.S.R. The author's own experiments were conducted on Swedish Spruce sawdust, comparative tests being carried out on sulphite cellulose and Pine sawdust. The main results were: (1) intense dry grinding of Spruce sawdust alters its solubility in lower alcohols, dilute acids and bases, and NH_4 oxalate solution; (2) up to 60% of the lignin content of the mechanically treated Spruce sawdust dissolves in *N*/20 NaOH at room temperature, with a simultaneous lowering of the OCH_3 content; (3) the uronic-acid content of Spruce sawdust and sulphite cellulose increases during the dry mechanical treatment; and (4) extraction with *N*/20 NaOH at room temperature dissolves from normal Spruce sawdust a small portion, but from the mechanically treated sawdust more than half of the uronic acids. [Forestry Abstracts, V. 14, No. 4]

Gran, G. Determination of alkoxyl groups III. An investigation on the determination of methoxyl in carbohydrate-containing substances [wood pulp, wood cellulose preparations and wood flour.] *Svensk Papp-Tidn.* 56 (5), 1953 (179–80.) 9 refs. P.R. [Forestry Abstracts, V. 14, No. 4]

Pigman, W., Anderson, E., Fischer, R., Buchanan, M. A., and Browning, B. L. Color precursors in Spruce- and Western Hemlock-woods and inner barks. *Tappi* 36 (1), 953 (4–12). 23 refs. P.R.

Inner bark of *Picea mariana* and wood of *Tsuga heterophylla* contain materials which develop a red color when treated with mineral acids, preferably in the presence of alcohols. These substances appear to be leucoanthocyanins. Descriptions are given of a systematic investigation on conditions affecting the tests, and of two semiquantitative methods for the determination of these substances. The leucoanthocyanins are found in the inner bark and cambium but not in the wood of *P. mariana.* Related materials in both water-soluble and water-insoluble forms are found in all fractions of the wood, inner bark, and

cambium of *T. heterophylla*. The composition of the leucoanthocyanin from the inner bark of *P. mariana* has been studied, it appears to have the formula $C_{15}H_9(OH)_3(OCH_3)(C_6H_{11}O_6)$. [Forestry Abstracts, V. 14, No. 4]

Veneers and Plywood

Miller, D. G. A preliminary investigation of veneer cutting properties of Aspen Poplar. *Mimeo. For. Prod. Lab., Can.* No. *O*-167, 1952. pp. 9 + 5 photos + 3 dgms.

In tests on a small shipment of logs of *Populus tremuloides* optimum lathe settings (knife angle 90° 30′ and 90° 0′, horizontal opening of pressure bar. 0.058 and 0.115 in. and horizontal opening 0.016 and 0.032 in. for $\frac{1}{16}$-in. and $\frac{1}{8}$-in. respectively) were determined. In tests on 8 representative bolts yields of 70% of the log volume were obtained, 49% grade 1, 21% grade 2 and 30% grade 3. The veneers dried and glued satisfactorily. [Forestry Abstracts, V. 14, No. 4]

King, E. P. A new or improved stiff laminated sheet material. *Brit. Patent* No. 684,086, Dec. 10, 1952. pp. 7. P.R.

A sheet material comprising a sandwich having a core between two outer layers of fibrous material, the core comprising a sheet or strip of (preferably light-weight) wood cut with the grain in the direction of the thickness of the sheet or strip and substantially perpendicular to its face, the outer layers being bonded to the faces of the sheet or strip by adhesive so that the grain of the wood extends substantially perpendicular to the outer layers. [Forestry Abstracts, V. 14, No. 4]

Cures for two veneering headaches: 1, Cracking, 2, Surface checking. *The Furnishing World,* Vol. 36, No. 642, 15 May 1953, p. 65.

The one simple effective remedy for cracking—to lay the decorative veneer with the grain perpendicular to the grain of the surface veneer of the panel—is often impracticable. Veneers laid in this way will resist cracking even when exposed to extreme variations in moisture content. If the veneer has to be laid parallel it is sometimes possible to incorporate a padding veneer laid perpendicularly between surface and decorative veneers. If both these precautions are impossible the initial moisture content and pressing conditions must be particularly carefully controlled. In general, panels from a hot press are more liable to crack than those veneered cold. The moisture content of the veneer is insignificant, but the initial moisture content of the plywood should be very low. Surface checks in veneered panels after finishing may occur because the veneer has been cut with a blunt tool or because a poor quality varnish was used. Best results are obtained if the tight face of the decorative veneer, rather than the loose face, is exposed. [Tech. Bul. F.D.C., V. 3, No. 17]

Pathology

Lohwag, K. Fauletypen des Holzes. [Types of wood decay.] *Holz Roh- u. Werkstoff* 11 (2), 1953 (54–7). 19 refs. [G.g.] P.R.

The generally accepted subdivision into stain, white-rot, and brown-rot fungi can serve as a basis for the classification of the wood-attacking fungi. In doubtful cases a differentiation between the white-rot ('corrosive', predominantly lignin-destroying) and brown-rot ('destructive', cellulose-destroying) fungi can be carried out by Bavendamm's physiological method. Different types of fungal attack are described. External similarities of 'red strip' *(Stereum sanguinolentum)*, red rot (*Fomes annosus*) and the initial stage of *Lenzites* rot are stressed. In addition to the three main types of fungal attack, the author mentions the 'double rot' ('Pine-kernel rot') of *Stereum frustulosum* followed by *Polyporus sulphureus*. [Forestry Abstracts, V. 14, No. 4]

Pearl, W. L. A method for the estimation of decay in Douglas-Fir wood chips. *Tappi* 36 (3), 1953 (133–6). 6 refs. P.R.

Presents a method for the estimation of the amount and type of decay ('white-pocket' rot, 'brown' rot, and 'dote') in Douglas Fir wood chips. Including the time necessary for drying the sample, 36–48 hours are required to carry out the test; it is said to determine the relative amounts of the predominant type of decay within limits of 5–10%. The method is based on the colours of (1) the filtrate from a boiling-ethanal extraction of the ground sample, (2) the solution after boiling the ground sample in water for a given time (5 min.), and (3) the boiling-water extract after treatment with a small amount of caustic alkali. [Forestry Abstracts, V. 14, No. 4]

Preservation

Keino, K. [The effect of copper salts on the mycelial growth of wood-destroying fungi. II. The destruction of wood impregnated with copper salts by Poria vaporario and Trametes sanguinea. III. Retention of the toxicity of copper salts against Poria vaporaria.] *Bull. For. Exp. Sta. Meguro, Tokyo No.* 54, 1952 (1–44). 44 refs. [Jap.e.]

[Cf. *For. Abstr.* 14 (No. 779).] (II) Samples of *Pinus densiflora* were impregnated with ammoniacal Cu-$(NH_3)_4SO_4$ solutions, at 0.6, 1.2, 2.5, 5.0 and 10% concentration, and set in cultures of *T. sanguinea* or *P. vaporaria* at 26° C. for 100, 200 and 300 days. The samples were analysed immediately after impregnation, during the drying after impregnation at the fibre-saturation point, and during decay, to determine changes in the composition of the cupricamino complex in the wood. After exposure to decay, the pieces were tested for loss of weight and compressive strength. The following results were obtained: (1) When $Cu(NH_3)_4SO_4.H_2O$ was dried for 24 hr. at 105° it lost NH_3 and water to become $Cu(NH_3)_2SO_4$. (2) When $Cu(NH_3)_2SO_4$ was kept in water for 5 days at room temperature, $(NH_4)_2SO_4$ separated out to give $CuSO_4.10CuO$, considerable amounts of which were found in control samples impregnated with 5% solutions of $Cu(NH_3)_4SO_4$. (3) Some wood components were chemically decomposed by the $CuSO_4.10CuO$ and perceptible amounts of oxalic acid were found. As a result, the compressive strength of control samples, apparently quite sound, decreased and the alkali extracts increased. Graphs showing the relationship of the treating concentration to alkali extract % and to the decreasing % of compressive strength are almost identical in shape. (4) Destruction of samples by *P. vaporaria* was accelerated with all solutions below 10%, while with *T. sanguinea* it was accelerated with the 0.6% solution only, and did not occur with solutions over 2.5%. (5) Acceleration of fungus decay with concentrations below 1.2% appeared to be caused by the action of $(NH_4)_2SO_4$ separating out. (6) Acceleration of decay by *P. vaporaria* in 2.5- and 5-% solution treatments may be caused by the following: (*a*) favourable conditions caused by the decomposition of wood constituents by $CuSO_4.10CuO$; (*b*) absorption of the Cu component by lignin liberated by the fungus, followed by reaction with oxalic acid also liberated by the fungus to give a substance temporarily named by the author 'lignin-copper-oxalic acid' (l.c.-o.a.) which is scarcely decomposed by cold N-H_2SO_4 solution; and (*c*) the combined action of fungal decay and 'l.c.oa.' in destroying wood. This theory is confirmed by the steady increase of cellulose consumption, especially during the later stage of the 300-day test, by the accumulation of the lignin component and by the increase of 'l.c.o.a.' in the residue at the end

of 300 days. (III) In tests with Cu arsenite and Cu arsenate: (1) Growth of *P. vaporaria* was inhibited at 0.2% with the arsenate and at 0.1% with the arsenite and also with Na arsenite, using the Petri-dish method. (2) The decaying action of the fungus was inhibited at 1.0% Cu arsenate and 0.5% Cu arsenite ammoniacal solutions in the test-block method. *From author's summary.* [Forestry Abstracts, V. 14, No. 4]

Sawing

Andrews, G. W., and Bell, G. E. Fundamental sawmill research: report No. 1. (Specific gravity of wood, depth of cut, and bite of tooth - in relation to power requirements.) *Mimeo. For. Prod. Lab., Can.* No. 0-168, 1953. pp. 10 + 8 photos + 2 dgms. + 5 gphs. 10 refs.

Direct relationships were found between sp. gr. (of 4 species, range 0.38 to 0.66), depth of cut, and size of bite (the distance each tooth advances in the cut/revolution) respectively and the h.p. required. The effect both of bite and sp. gr. appeared to be greater at higher saw speeds. [Forestry Abstracts, V. 14, No. 4]

Lapin, P. I. Skorostnoe pilenie na kruglopiljnyh stankah. [High-speed sawing with circular saws.] *Lesn. Prom.* 11 (1), 1951 (29–32). [Russ.]

Presents preliminary results of introducing high-speed sawing with circular saws in two Soviet mills, plus some theoretical considerations. Tabulates the maximum internal stresses occurring in circular saw blades of 500–800 mm. diameter working at usual speeds (peripheral speed ranging from ca. 50 to ca. 66 m./sec.). Investigations on blade vibration have shown that the frequency of the natural vibrations of a rotating circular sawblade bears the following relationship to the centrifugal force effect: $f^2_{dyn} = f^2_{st} + Bn^2$, where f_{dyn} is the frequency of natural vibrations of a rotating disk, f_{st} the frequency for a stationary disk, n = rev./sec. of the disk, and B is a coefficient depending upon the form of vibrations and varying, according to experimental data, from 1.8 to 5.9. It follows that high-speed work is associated with a higher frequency of natural vibrations, thus eliminating the danger of vibrations corresponding with any form of resonance. It has also been found that, in order to reduce disturbances causing forced vibrations in disks, it is imperative to increase the cutting speed. The recommended magnitudes of hammering are tabulated for blades of 400–700 mm. diameter, and for speeds of 1000 to 3000 rev./min. Two other tables give the recommended cutting speeds and feeds for (1) two-saw edgers, (2) dockers, (3) re-saws, and (4) 'lath' saw. [Forestry Abstracts, V. 14, No. 4]

Wood Machining

Kollmann, F. Das Spannen von Gattersagenblattern, insbesondere mit hydraulischen Spannvorrichtungen. [Tensioning of frame-saw blades, in particular by means of hydraulic tensioning appliances.] *Holz Roh- u. Werkstoff* 11 (4), 1953 (156–61). 6 refs. [G.] P.R.

Theoretical considerations of the tensioning of blades in a frame-saw, the decrease of tension due to the heating of blades during operation, and a brief description of mechanical tensioning devices, are followed by a detailed illustrated description of a hydraulic tensioning appliance introduced into the German sawmilling industry about 1942 and manufactured by several German firms. [Forestry Abstracts, V. 14, No. 4]

Pittman, H. B., Jr., and Johnson, E. S. Cost savings in furniture manufacture by accurate dimensional control. *Bulletin, Department of Engineering Research, North Carolina State College, Raleigh, N. C.* No. 53, 1952. pp. i + 53 + 28 tbls. 9 refs. P.R.

Shows that it is desirable to establish dimensional tolerances in furniture manufacture and maintain them by using gauges. This method of dimensional control should be followed by other systems of scientific management, operating in conjunction with the gauges. Presents two methods of gauging: (1) individual gauges for length and width of each part of each piece, and (2) adjustable or universal gauges with dial indicators. By using gauges, a saving of ca. 8% may be effected in direct cabinet-room labour. For the average furniture plant, a system of individual gauges would cost ca. $4600 per year; for adjustable gauges, the annual cost on a 5-year basis would not exceed $300. [Forestry Abstracts, V. 14, No. 4]

Sherlock, F. E. The automatic spindle shapers: parts 1–2. *Wood,* Vol. 18, Nos. 5–6, May–June 1953, pp. 196–8, 234–7, 11 illus.

The range of machines available for shaping and moulding is large; these articles deal with the general principles of design and operation of automatic spindle shapers and their advantages over the router, and single and double spindle moulders.

In describing the general principles of the automatic shaper, the author explains how the design of the individual machines differs for particular kinds of work, such as shaping chair legs. An ingenious mechanism is incorporated in most of the machines, which can be set so that the table slows up when the cut is particularly heavy and when difficult grain or corners are involved. The rotation of the table can be adjusted to speeds of about 15–120 sec. per rev., so that simple components can be machined at a rate of as many as 4 per min.; the uses of this system are described. Cutter head speeds range from 7200 to 10000 rpm. The advantages of double headed machines are explained.

In part 1 there is a description of an automatic shaper with a large rotating table; this is essentially for the manufacture of long runs of standard parts. Machines are also designed specially for short runs repeated at intervals and for shaping small parts. Examples of these machines described in the second part include the small automatic shaper with rotating stations sometimes known as the automatic router, the small double rotating table type machine and the automatic jig feed spindle shaper. [Tech. Bul. F.D.C., V. 3, No. 17]

Drawers

Plastic drawer units in modern wood furniture. *Upholstering* U.S.A., Vol. 20, No. 3, March 1953, pp. 102–3, 3 illus.

Warren Furniture Manufacturing Co. U.S.A. are fitting moulded Bakelite phenolic drawers into furniture made in ash-blonde korina (afara), dark mahogany or greyish limed oak. The drawers hold more than wooden ones of the same external dimensions and are easy to keep clean because they have no cracks or joints to hold the dust. The drawers run easily and are not affected by temperature or humidity.

There are illustrations of contemporary furniture with drawers of this type which have been designed to show that wood and plastic are compatible. [Tech. Bul. F.D.C., V. 3, No. 17]

Drawer side stabilization. National Lumber Manufacturers' Association, April 1953, 9 pp. illus.

It has been estimated that, in most cases, drawers could be prevented from sticking if 20–30% of the expansion in the sides due to increases in humidity could be prevented.

With this in mind four tests were carried out on wood dipped for 30

sec. in a water-repellent compound, in the same compound with 2% of wax added, in a high quality lacquer and in a phenolic base varnish, respectively. In each case the results showed that the stability of the wood had been increased.

Treatment with one of the substances tested is one way in which the swelling of drawer sides can be reduced. At the same time closer attention should be given to drawer fitting clearance tolerances, and centre guides should be installed on the bottom of the drawers so that they slide between strips glued to the frame.

In many cases the problem has been solved by the use of timber with a moisture content of 12–15%. [Tech. Bul. F.D.C., V. 3, No. 17]

Glues and Gluing

Thomson, A. G. Tropical tests for glues. *Adhesives and Resins,* Vol. 1, No. 2, May 1953, pp. 61–2.

The Forest Products Research Laboratory have recently established a testing station where the effect of tropical climates on glued assemblies and on operations such as gluing-up furniture can be assessed. In one room the temperature varies from 84° to 77° F. and the humidity from 93% to 75% to simulate the wet season in countries such as India. In another room the temperature rises gradually from 82° F. to 103° F. each day while the relative humidity ranges from 40% to 20%. This is intended to resemble the dry season in tropical countries. To compare the effects of these rooms with the effects of the actual climate, experiments are now being carried out in collaboration with the Tropical Testing Station in Nigeria. A third room is arranged so that it can be kept at any constant pre-arranged set of conditions.

Glue manufacturers can arrange to send samples of products intended for export to be stored for a few months in any of these rooms to see how they behave. Various types of glues, ranging from synthetic resins to caseins and animal glues, are at present under test. [Tech. Bul. F.D.C., V. 3, No. 17]

Plath, Erich. Wood gluing. Wissenschaftliche Verlagsgesellschaft m. b. H, Germany, 1951, 200 pp., 63 figs., 53 refs., DM 12.50 (in German).

This book contains a survey of the whole subject of wood-gluing. About half of it is devoted to the adhesives themselves which are divided into five groups. These are bone and hide glues, blood albumen glues, casein glues and two sections on synthetic resin glues. The nature and properties of each group are described together with the appropriate methods of testing. A clear, brief summary concludes each section. The synthetic resins that are described include melamine-formaldehyde as well as the more familiar phenol- and urea-formaldehyde. Adhesives based on poly-urethane, resorcinol formaldehyde and dicyandiamide formaldehyde are more briefly mentioned.

The section devoted to particular glues is preceded by an outline of the chemical and physical fundamentals necessary to general understanding of gluing processes. These are treated comprehensively and include a brief explanation of colloid chemistry, the setting process and the sources of the strength of the finished joint. Theoretical matters are not however stressed at the expense of practical ones and the book is written essentially to summarize the practical aspects of wood-gluing.

One section is devoted to testing methods and this describes not only the standard methods of joint testing but measurement of viscosity, acidity, solids content and strength. The last section is devoted to special topics such as the methods of accelerating the setting of adhesives by heat and special forms of adhesive such as prepared film glues. A glossary of gluing terms is provided. [Tech. Bul. F.D.C., V. 3, No. 17]

English Research

Forest Products Research 1952. H. M. Stationery Office, London, 1953, 62 pp., 8 illus., 3*s*.

Experiments were started at the Forest Products Research Laboratory last year to obtain information on factors which affect the shrinkage of wood during drying. Results so far have confirmed the general finding that green beech dried at high temperatures shrinks and distorts more than air-dried beech.

In the woodworking section a study of the action of saw teeth has provided information from which it has been possible to formulate a theory of cutting. During this study observation of the behaviour of the wood fibres at the cutting edge provided an explanation of the characteristic change in shape of the edge as blunting occurs. Investigations on circular saws have included comparative tests of the performance of standard, treated and Stellite-tipped inserted teeth. Compared with the standard teeth the performance of the Stellite-tipped teeth was considerably better than in tests carried out in a Colonial sawmill, which indicates that the benefit derived from tipping the teeth depends largely upon the care taken in preparation and use of the saw. Other sawing tests have included measurements of power demand of narrow bandsaws at different feed speeds and tooth pitches, and the trial of a carbide circular saw specially designed for cutting resin-bonded chipboards. A report dealing with investigations on spring-set circular plate saws has been prepared. Information has been given on saw performances in relation to feed speed, depth of cut, hook, number of teeth and density of timber cut. Particular attention was paid to saws with comparatively few teeth; it appears that the optimum number of teeth depends on the particular application of the saw.

A full-scale investigation in planing was started, to establish relationships of the power demand, feed resistance, quality of finish and cutter wear to the cutting conditions for different timbers. Extensive tests have also been carried out in cutting along the grain at different depths of cut and at cutting angles of 0°–40°.

Various timbers have been tested to determine the power requirements in boring flat-sawn and quarter-sawn material, the suitability of particular types of boring bit for different species and the effect of blunting on power and quality of finish. A preliminary study of the cutting action in boring has been made with the aid of high speed photography.

Stacks of oak treated in May 1951 with 5% DDT emulsion in water or a 1% gamma isomer of benzene hexachloride spray and then exposed to attack by Lyctus brunneus have been investigated. The results confirm previous indications that this type of treatment is insufficient to prevent attack in parts of the stack furthest from the point of application.

Investigations of the value of the addition of DDT to phenol formaldehyde adhesives for the prevention of Lyctus attack in plywood have been completed. The presence of 2% technical grade DDT will prevent infestation in 3-ply obeche if it is exposed to attack two months after manufacture; the full period of protection afforded has not yet been determined.

General biological work on Anobium punctatum has included investigations of the conditions in timber suitable for larval development and of the toxicity of hydrocyanic acid to the eggs and larvae. [Tech. Bul. F.D.C., Vo. 3, No. 17]

National Meeting Abstracts

Following are abstracts of some of the papers that will be presented at the 8th Annual FPRS Meeting in Grand Rapids, Mich., May 5, 6, 7.

Alleviating Bow and Crook in Southern Yellow Pine Dimension with Chemicals. W. W. King, Acting Head, Forest Products Department, Texas Forest Service, Lufkin, Texas. A study was made to find a practical means to alleviate bowing and crooking of southern yellow pine dimension, exclusive of lamination. Nine commercial chemical compounds and two water proof papers were utilized in the experiment involving 6400 pieces of #2 grade, southern yellow pine 2 x 4's eight feet long. An analysis was also made of eight characteristics of 2 x 4 studs describing tree growth and manufacturing practices. The results show that producers of southern pine dimension should sort their logs and alter sawing practices to the largest extent economically feasible. This action would be required preliminary to the use of chemical compounds for stabilizing purposes.

The Modern Superheated-Steam Kiln. J. S. Mathewson, Forest Products Laboratory, Madison, Wis. Paper will include a brief history of superheated-steam kilns and describe the construction and operation of these kilns. German, Australian, and Canadian investigators have reported marked reductions in the time and heat energy required to dry air-seasoned softwoods. Some of the results thus obtained will be submitted.

Evaluation of Glues and Glued Products. Richard F. Blomquist, Forest Products Laboratory, Madison, Wis. Both the initial quality of a glue joint and its durability under expected service conditions are important considerations in the selection of a woodworking glue. Factors that influence the deterioration of glued joints in wood include mechanical stresses as a result of dimensional changes in the wood, moisture, heat, and microorganisms. Presently available methods for evaluating the durability of glued joints include long-term exposures to controlled-laboratory conditions and to weathering actual service tests, and accelerated durability tests. The advantages and limitations of each of these procedures is reviewed with typical examples. The need for further coordinated service testing and development of more reliable accelerated durability test methods for glues and glued products offers a challenge to the Society and its members.

Factors to be Considered in Force Drying Wood Finishes. K. R. Brown, Sherwin–Williams Company, Chicago, Illinois. This paper discusses some of the formulation requirements of the various wood finishing materials that are to be force dried. It also points out the need for thorough consideration of all factors involved in the finishing materials, the wood article being finished and subsequent production methods to be employed before installation of force drying equipment.

Testing of Finishing Materials For Woodwork. Donald G. Lubeck, The Singer Mfg. Co., South Bend, Ind. The testing of finishing materials for use on woodwork must rely on a combination of empirical and standardized methods. The final evaluation of any material is by necessity a combination of the operators' opinions and the results obtained with standardized equipment.

The testing of finishing materials, to be used on Singer cabinetwork, is conducted by chemists and engineers familiar with the relationship existing between laboratory analysis and production application. The paper, "Testing of Finishing Materials for Woodwork" is a summary of the tests conducted at South Bend.

Survey of Grades in the Hardwood Plywood Industry. John L. Butler, Laboratory and Inspection Service, Hardwood Plywood Institute, Chicago, Ill. This paper discusses the results of a survey to determine the points of difference between grading practices of the Hardwood Plywood Industry and grade requirements set forth in the Hardwood Plywood Commercial Standard CS35–49. During the course of this investigation panels deemed to be under-grade by their failure to strictly comply with commercial standards were classified into one of twenty defect categories indicative of the reason for the rejection. An analysis of these categories reveals the need for more realistic grade descriptions and also suggests certain categories as being worthy of increased vigilance on the part of quality control personnel.

Translating Quality Control Facts into Action. W. F. Price, The Singer Mfg. Co., South Bend, Ind. Although technical considerations are of principal importance in a statistical quality control program, two other factors that contribute to the program's success are; (1) an organizational set-up that definitely recognizes quality control as a top level function and (2) the development of a system that disseminates the collected information both promptly and accurately to all interested parties. This paper describes some of the organizational problems and gives examples illustrating ways and means by which quality control facts are translated into action.

Cushioning Furniture to Prevent Damage. E. F. Landt and K. Q. Kellicut, Forest Products Laboratory, Madison, Wis. The application of fiberboard and cushioning materials in packaging of furniture are discussed. Included in the paper are illustrations of actual methods currently being used by furniture manufacturers in the Southeastern United States.

Extruded Composition Board. John M. Crafton, Chipcraft Co., Morristown, Tenn. Paper will present a general cost outline, and review equipment, raw material, chemicals, labor, and other factors pertaining to the manufacture of extruded wood particle board. Additional points to be covered include Quality Control, Flexibility of the extrusion process, Numerous applications where chipcore is not a substitute material. Actual production records will be given, and a 12 minute movie will show the "Chipcraft" extrusion system in operation.

Vapor Drying of Some Western Woods. W. R. Cantrell, Taylor-Colquitt Co., Spartanburg, S. C. Using the Vapor Drying Process, such species as Douglas-fir, ponderosa pine, white fir, western hemlock, Pacific madrone and California black oak have been seasoned on a laboratory and pilot plant scale. This paper presents data and results obtained from this experimental work.

Steam Consumption in the Kiln Drying of Western Softwoods. Virgil C. Davis, The Booth-Kelly Lumber Co., Springfield, Ore. This is a study of data collected from the drying of 25 million feet of Douglas Fir and Western Hemlock. The equipment used was a battery of 10 R. A. Simmons cross circulation interal fan kilns all single track 103 feet long. The steam is measured at the Booth Kelly Lumber Company by a Bristol mechanical flow meter. This is the restricted flow type.

This study includes total footage dried, Total pounds of water evaporated, pounds of steam consumed per pound of water evaporated, and pounds of steam consumed per thousand board feet dried.

ALABAMA
W. T. Smith Lumber Co., Chapman

ARKANSAS
Bradley Lumber Co. of Arkansas, Warren
The Crossett Co., Crossett
Dierks Lumber & Coal Co., Mountain Pine
Southern Lumber Co., Warren

CALIFORNIA
California Redwood Association, San Francisco
L. J. Carr & Co., Sacramento
Crane Mills, Corning
Ivory Pine Co., Dinuba
National Wood Treating Corp., Oroville
Scott Lumber Co., Inc., Burney
Tarter, Webster & Johnson, Stockton
Winton Lumber Co., Martell
E. K. Wood Lumber Co., San Francisco

GEORGIA
Southern Wood Preserving Co., Atlanta

IDAHO
Potlatch Forests, Inc., Lewiston

ILLINOIS
General Electric, Illinois Cabinet Plant, Rockford
Greenlee Tool Co., Rockford
Edward Hines Lumber Co., Chicago
Illinois Interior Finish Co., Chicago
Johnson & Carlson, Chicago
Masonite Corp., Chicago
Mattison Machine Works, Rockford
Pressed Steel Car Co., Inc., Chicago
Sherwin-Williams Co., Chicago
Steger Furniture Mfg. Co., Steger
Wood & Wood Products, Chicago

INDIANA
The Dunbar Furniture Mfg. Co., Berne
National Homes Corp., Lafayette
The Wood-Worker & Veneers and Plywood, Indianapolis

IOWA
Curtis Co. Inc., Clinton

LOUISIANA
A. J. Hodges Industries, Inc., Shreveport
Louisiana Long Leaf Lumber Co., Fisher

MARYLAND
National Store Fixture Co., Inc., Odenton

MASSACHUSETTS
Draper Corp., Hopedale
Heywood-Wakefield Co., Gardner
A. G. Spalding & Bros., Inc., Chicopee

MICHIGAN
Baker Furniture, Inc., Grand Rapids
The Dow Chemical Co., Midland
Everett Piano Co., South Haven
The Lloyd Manufacturing Co., Menominee

MINNESOTA
Mereen-Johnson Machine Co., Minneapolis
Rilco Laminated Products, Inc., St. Paul
Wabash Screen Door Co., Minneapolis

MISSOURI
Monsanto Chemical Co., St. Louis

NEVADA
Vaughn Millwork Co., Reno

NEW YORK
American Defibrator, Inc., New York
Borden Co., New York
Peter Cooper Corps., Gowanda
Oval Wood Dish Corp., Tupper Lake
Reichhold Chemicals, Inc., White Plains
United States Plywood Corp., New York

NORTH CAROLINA
The Champion Paper & Fiber Corp., Canton
Deluxe Saw & Tool Company, High Point

OHIO
The Baker Wood Preserving Co., Columbus
The Baldwin Co., Cincinnati
Buckeye Screen & Weatherstrip Co., Columbus
Coe Manufacturing Company, Painesville
The Kirk & Blum Mfg. Co., Cincinnati
Moraine Box Company, Dayton

OREGON
Cascades Plywood Corporation, Portland
Evans Products Co., Coos Bay
J. Neils Lumber Co., Portland
Oregon Lumber Co., Baker
Stimson Lumber Co., Forest Grove
West Coast Lumberman's Assn., Portland

PENNSYLVANIA
Blaw-Knox Company, Pittsburgh
Firth Sterling Steel & Carbide Corp., Pittsburgh
Frick Company, Waynesboro
Gunnison Homes, Inc., Harrisburg
Koppers Company, Inc., Pittsburgh
Perkins Glue Co., Lansdale
Wood Metals Industries, Inc., Kreamer, Snyder County

SOUTH CAROLINA
Lightsey Brothers, Miley

TENNESSEE
E. L. Bruce Co., Memphis
Chapman Chemical Company, Memphis
Memphis Hardwood Flooring Co., Memphis
Nickey Bros., Inc., Memphis
Tenn. Products & Chemical Corp., Chattanooga

TEXAS
Wm. Cameron & Co., Inc., Waco
Kirby Lumber Corporation, Houston

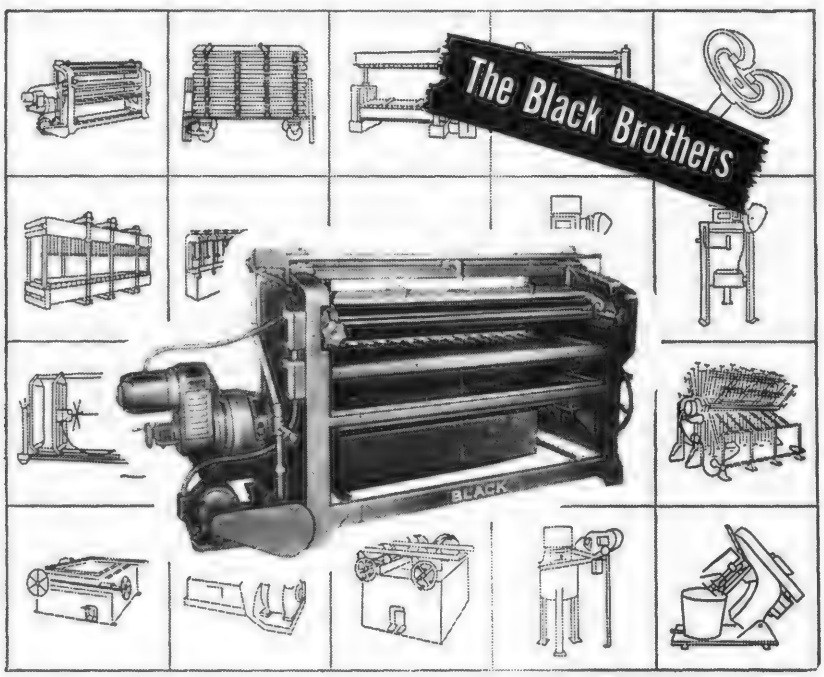
VERMONT
Fyles & Rice Co., Inc., Bethel

WASHINGTON
American Marietta Co., Seattle
Deer Park Pine Industry, Inc., Deer Park
Douglas Fir Plywood Association, Tacoma
Eatonville Lumber Co., Tacoma
The Long-Bell Lumber Co., Longview
Simpson Logging Co., Shelton
Weyerhaeuser Timber Co., Tacoma

WISCONSIN
The Buckstaff Co., Oshkosh
Harnischfeger Corp., Port Washington
Holt Hardwood Co., Oconto
Marathon Corp., Rothschild
Mosinee Paper Mills Co., Mosinee
D. J. Murray Mfg. Co., Wausau
Paine Lumber Co., Oshkosh
Rhinelander Paper Co., Rhinelander

ALASKA
Ketchikan Spruce Mills, Ketchikan

CANADA
British Columbia Lbr. Mfrs. Assn., Vancouver, B. C.
Canadian Forest Products Limited, New Westminster, B. C.
Dominion Electrohome Industries, Ltd., Kitchener, Ont.
The Knight Mfg. & Lbr. Co. Ltd., Meaford, Ontario
MacMillan & Bloedel Limited, Vancouver, B.C.
A. S. Nicholson & Son, Ltd., Burlington, Ont.



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FPRS NEWS-DIGEST

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Volume IV FEBRUARY, 1954 Number 2

J. P. WEYERHAEUSER

Annual Meeting Luncheon Speaker Is Leader in Forest Resources Utilization

J. P. Weyerhaeuser, Jr., president of Weyerhaeuser Timber Company, Tacoma, Washington, will be the principal speaker at the official luncheon of the Forest Products Research Society's Eighth National Meeting to be held May 5, 6 and 7 at Grands Rapids, Michigan.

Mr. Weyerhaeuser is one of the leaders in the development of sound, continuous-yield forest-management practices and in promoting the fullest possible utilization of our forest resources.

A recent significant indication of this interest in assuring a renewable and totally useful resource has been Mr. Weyerhaeuser's announcement that Stanford Research Institute at Palo Alto, California, has been retained to conduct an impartial and thorough study of the future demand for American and Canadian forest products.

Since the beginning of the century lumbermen and pulp manufacturers have been vexed by a number of seemingly unanswerable questions. As the population and economy of the United States expanded, the per capita use of lumber declined and the consumption of pulp and paper products skyrocketed.

Mr. Weyerhaeuser said, "Our firm has asked Stanford to take a long look at the future demand for lumber, plywood, pulp and paper, wood fiber products, and other forest products. We want to know the trends in construction and more about the competition, both present and future, between various building materials so that we will have an indication of tomorrow's log requirements.

"The study will go further than merely considering the competition between wood products and materials of other industries. It will attempt to illuminate the intra-industry competitiveness (for example, of hardboards, plywood, softboards, sheathing lumber, fiberboard, containerboard, and wooden boxes.

"Stanford will attempt to predict how much of the increasing pulp, fiber, and board requirements can be met through a better integration of lumber, plywood, and pulp operations, and by industries better serving the small woodlot owner who currently hasn't much of a market for his crop."

After Stanford makes its complete report to Weyerhaeuser, the firm intends to publish the results.

Mr. Weyerhaeuser has been president of Weyerhaeuser Timber Company since 1947 and was executive vice-president from 1933 through 1946.

Weyerhaeuser Timber Company employs more than 14,000 employees, has four pulp mills, a plywood plant and eight sawmills centers in Oregon and Washington with sustained timber crops from 2½ million acres of tree farm lands.

Competitive Picture Highlights Importance of FPRS Annual Meeting

It is generally conceded by various authorities in the forest products industries that 1954 will continue to be another banner year for wood—but not without plenty of stiff competition, both from within the industry and from other industries. Home builders are generally optimistic, planning to maintain or increase the near-record construction volume attained in 1953. New home production for 1953 was estimated at 1,100,000 units. The pre-fabricated housing industry expects to more than double its 1953 production. One firm alone anticipates an increase from 12,738 units in the year spanning 1952–53 to 37,500 units in the year '53–'54. Over-all national construction set a new record in '53, with residential building alone up 7%. Leo V. Bodine, Executive Vice President of the National Lumber Manufacturers' Association, predicts that lumber's share of the home building market will increase perhaps as much as 10%.

Wood household furniture also reached an all-time high in 1953. Experts anticipate that 1954 will be one of the four best years in furniture history. One big contributing factor is the soaring United States birth rate which is bringing out a boom in school construction, school furniture and allied products. Commenting upon the business outlook, Frank E. Seidman, furniture industry financial spokesman, states: "For the furniture manufacturer, 1954 is sure to be a year of keen competition for the consumer's dollar, and competition from within the industry for the furniture dollar."

And from the Lumber Survey Committee to the Secretary of Commerce comes this report—that predictions of generally favorable business conditions in 1954, along with forecasts of a substantial volume of construction, indi-

cate a good potential demand for lumber.

However, along with all of these optimistic reports, the outlook is tempered by a recognizable and growing swing back into a buyer's market, necessitating more aggressive marketing techniques, streamlining of operations, to obtain increased efficiency in both manpower and materials, and continued development of improved products or precesses that will compete with materials competitive to wood.

•Carl A. Rishell, Director of Research, National Lumber Manufacturers' Association, puts it this way: "Highly competitive markets are giving impetus to lumber and wood products research in all industries dealing with forest products and their derivatives. The trend is gaining momentum as more and more manufacturers, preparing to meet this competition, seek improvement of their present products and development of new ones."

What Does It All Add Up To?

As President of FPRS, Robert D. Pauley, emphasizes in his editorial in this issue, the FPRS 8th Annual Meeting at Grand Rapids, Michigan, May 5–6–7, in cooperation with the 1954 Woodworkers' Industry Show, provides every farsighted member of the wood industry a double-barrel opportunity. First, he will be on the scene to obtain new and previously nonpublished technical information to assist him in the manufacture and sale of his products; and, second, since the last war, there have been numerous important improvements in all types of woodworking machinery. To the man thinking in terms of cutting costs and producing improved products at a faster rate and of meeting his comwant to attend the FPRS Annual Meeting and the Woodworker's Industry Show.

FPRS NOMINEES

(Continued from page 7A)

wood Association, Tacoma, Washington to succeed Fred A. Armbruster, the Dow Chemical Co., Seattle, Washington for a 3 year term of office.

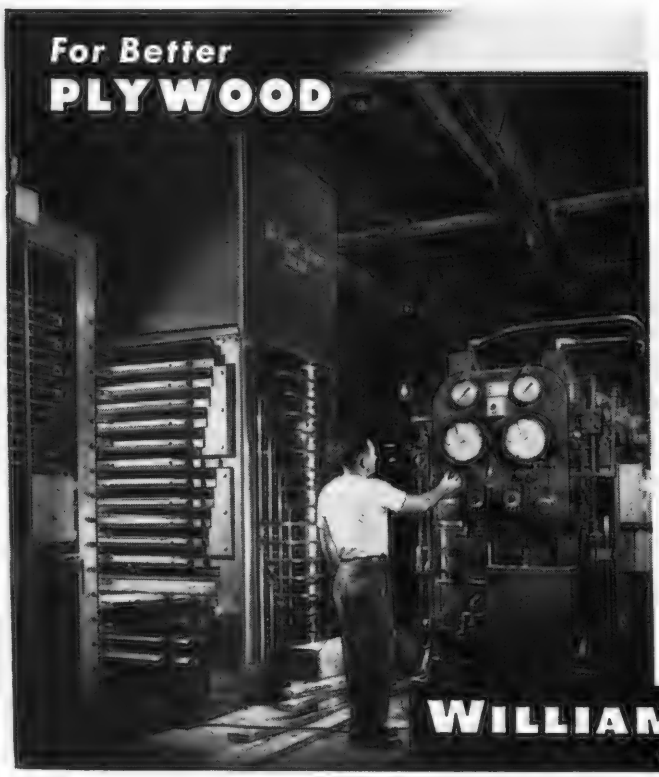
Northeast Regional Board Member —Frank T. Parrish, Heywood-Wakefield Co., Gardner, Mass. has been nominated to succeed W. Burdette Wilkins, consultant, Ridgewood, N. J. for a 3-year term of office. Mr. Parrish is currently Chairman of the Northeast Section of the FPRS.

Other regional board members continuing in office in 1955 are: Southeast, Dr. E. S. Harrar, Duke University, Durham, N. C.; North-Central, Dr. J. A. Hall, Forest Products Laboratory, Madison, Wis.; South-Central, W. J. Eason, Nickey Brothers, Inc., Memphis, Tenn.; and Southwest, R. E. Shreck, Union Lumber Co.; San Francisco, Calif.

Candidates for the 1955 National Nominating Committee of which 4 are to be elected are: Arthur B. Anderson, University of California, Berkeley, Calif.; A. R. Colman, Bell Telephone Co., of Canada, Montreal, Canada; Robert B. Fellows, Reichhold Chemicals, Inc., Jacksonville, Fla.; Ira Hatfield, Monsanto Chemical Co., St. Louis, Missouri; George G. Marra, Washington State Institute of Technology, Pullman, Washington; Herbert B. McKean, Timber Engineering Co., Washington, D. C.; George W. Stanley, Jr., Solar Sturges Div. of Pressed Steel Car Co., Chicago, Ill.; and Frederick F. Wangaard, Yale University, New Haven, Conn.

Subject Matter Committees to Play Key Part at FPRS National Meeting

At the May 5, 6, 7, 1954 FPRS 8th Annual National Meeting at Grand Rapids, Michigan, the thirteen FPRS Subject Matter Committees will play an increasingly important role in the



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advancement of technical information in specific areas of wood technology.

These Subject Matter Committees are organized into the following divisions, and each will have a separate committee meeting over-and-above the eight technical sessions scheduled during the formal program. The committees, headed by General Subject Matter Committee Chairman and FPRS Vice-President Moss B. Christian, Chicago Mill & Lumber Co., include: Wood Machining & Equipment, L. A. Patronski, Wabash Screen Door Co.; Wood Preservation, W. N. Darwin, Tennessee Valley Authority; Wood Drying, R, C. Rietz, U. S. Forest Products Laboratory; Logging and Milling, F. C. Simmons, U. S. Forest Service; Packaging, E. R. Stivers, Package Research Laboratory; Wood Composition Materials, G. G. Marra, Washington State Institute of Technology; Forest Products Education, R. W. Wellwood, University of British Columbia; Glues & Gluing, Alan A. Marra, University of Michigan; Wood Finishing, B. E. Clatworthy, Radio Corporation of America; Quality Control, C. Latimer, Nickey Brothers, Inc.; Chemical Utilization, R. C. Sproull, Herty Foundation; Veneer & Plywood, H. O. Fleischer, U. S. Forest Products Laboratory, and Dr. J. S. Bethel, North Carolina State College; and Marketing, P.H.W. Creden, Edward Hines Lumber Co.

The Subject Matter Committees were formed: (1) to give persons with interests in these specific fields an opportunity to interchange information and discuss specialized problems through the medium of FPRS publications and meetings; (2) to review past accomplishments and plan future activities in the particular field of interest (this is done at the annual meeting held in conjunction with the FPRS annual National Meeting); (3) to prepare and present annual reports as part of the proceedings of the annual FPRS meeting. These reports record and evaluate pertinent information of significance in the subject matter field of interest to the forest products industries. The initial report of each Subject Matter Committee is a comprehensive statement defining and recording the status of research and development activities in the subject matter field; (4) to pioneer and develop specific material and engage in activities within the scope of the subject matter field; and (5) to work with the annual FPRS Meeting Program Chairman in planning and developing the technical session program as scheduled by the FPRS Executive Board.

All interested persons are invited to attend FPRS Subject Matter Committee meetings and enter into discussion.

Five Plants to Be Toured at the Eighth National Meeting of the Forest Products Research Society, May 5, 6 and 7

Registrants of the Eighth National Meeting of the Forest Products Research Society May 5, 6, and 7 will have their choice of visiting any and all of five interesting, leading wood industry manufactures at Grand Rapids, Michigan, during the plant tours scheduled Wednesday morning and afternoon, May 5:

(1) Registrants will have the opportunity to view the step-by-step operations of the modern manufacture of some of the very highest quality furniture produced in America. Modern, efficient kilns, imaginative (modified) kiln schodules, and practical moisture control measures within the plant of John Widdicomb Company have enabled the firm to meet the demand for large production without the sacrifice of quality, according to company officials.

John Widdicomb Co. today is one of the largest producers of fine household furniture in the Grand Rapids area. Long known for its superb cabi-

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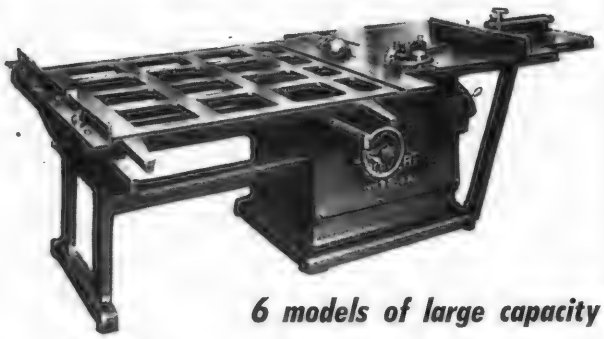

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Formerly Forest Inspector, U. S. Forest Service

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CONTENTS

1. Growing wood as a farm crop
2. Starting a farm forest
3. Weeding and releasing young trees
4. Thinning tree crops
5. Pruning tree crops
6. Cutting the wood crop
7. Marketing wood products
8. Managing the farm woods for maple sap
9. Managing farm woods for Christmas trees
10. Managing farm woods for naval stores

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FOREST PRODUCTS

By NELSON C. BROWN, *formerly of Syracuse University.* Discusses the harvesting, processing, and marketing of materials other than lumber, including the principal derivatives, extractives, and incidental products in the United States and Canada. "Discusses recently developed uses—such as rayon, wood sugars, plastic and clothing — for wood pulp, and comments upon the importance of many older products. Stressing . . . recent trend to utilize many materials wasted until recently . . . the book suggests many ways in which such wastes may be turned into profitable materials."—*Paper Industry. 1950. 399 pages. $6.00.*

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net making and fine period reproductions, particularly French court and provincial styles, the company in recent years has achieved recognition for its modern and contemporary furniture designs.

(2) The American Seating Company is a tremendous operation. With three-quarters of a million square feet of floor space and over two thousand employees, it is said to be the largest producer of school seating in the U. S.

Many of the innovations developed by American Seating Company have since become the standard of school systems.

They are also outstanding for products furnished for churches, theater seating, stadium seating, transportation seating, and a long list of military products.

(3) For those who wish to view the production of high-quality upholstered furniture, the Mueller Furniture Company will prove extremely interesting.

The Mueller Co. is one of the fine old companies producing quality furniture in Grand Rapids. The third generation of the Mueller family is now very active in the affairs of the company. The company dates back to 1892.

They are best known for their fine upholstered furniture, but also produce a limited line of occasional tables. Theirs is an excellent example of the combination of fine craftmanship with the latest developments in wood technology.

(4) Highly skilled production line and custom manufacture of executive office furniture will be shown by the Stow-Davis Furniture Company. The company produces a full line of wooden office furniture from letter trays to board-room tables. The company's standard line runs through many style fields, but its outstanding work in the custom field is its pride.

Stow-Davis Furniture Co. traces its founding back to 1880, when it was organized to produce kitchen tables. Today it employs 275 people.

(5) Visitors going through the Grand Rapids Varnish Corporation plant will gain an insight into the production of industrial finishing materials. The different types of finishes, their production, requirements, composition, materials, qualities, and serviceability will be explained.

Last year the company produced 3,750,000 gallons of finishing materials. Approximately 60 per cent of this material was in wood finishes.

Among the products on which the Grand Rapids Varnish Corporation's industrial finishes are used are: furniture, radios, television sets, pianos, major appliances such as refrigerators, laundry equipment, and automotive and aircraft parts and assemblies.

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Assignment to Philippines

George M. Hunt, a charter member of FPRS and a former director of the U. S. Forest Products Laboratory, Madison, Wis., is scheduled to leave Madison about March 1 for the Philippine Islands where he will serve for a year as a Forestry Officer of the Food and Agriculture Organization of the United Nations. Mr. Hunt's assignment is to work with representatives of the Philippine Bureau of Forestry to assist in the establishment of a Philippine Forest Products Laboratory near Manila. The laboratory building is now under construction and some of the equipment has been purchased.

Preparatory studies and recommendations for the establishment of the new laboratory were made by Mr. Winslow L. Gooch.

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Increased Membership Means Added Benefits from FPRS

New benefits are in the offing this year which mean an increase in the services of the society at no extra cost to you. An additional FPRS Journal will be published, making a total of six Journals in 1954. The 1954 national meeting promises to be the best-ever meeting. An industry machinery show will be held in conjunction with the FPRS national meeting at Grand Rapids, Michigan. Although the industry show is not officially sponsored by the FPRS, the sponsors, Sandy Stuart of the John Widdicomb Company and Bob Hiller of American Cyanamid are both members of the FPRS. Therefore, in addition to all the technical sessions and events of the FPRS national meeting, the attendees will also be able to see and enjoy the machinery show which will feature newly engineered machines actually running and doing the various jobs they were designed to perform.

Two new subject matter committees have been recently formed which hold promise of resulting in more and better information to the individual members. The committees are: *Marketing*, under the chairmanship of Phil Creden of Edward Hines Lumber Company; and *Logging and Milling*, chairman, Fred Simmons of the Northeast Forest Experiment Station. Another committee on *Veneers and Plywood* has been temporarily set up but this awaits confirmation of a permanent status.

These benefits are resulting from primarily one thing—an increase in membership. It stands to reason that by building up the *total* membership the society is in a stronger position to offer more and more value to the *individual* member. You can help by sending in the names of friends and business acquaintances whom you feel would benefit by becoming members. If you have a sincere desire to help build the society so that it can be of better service to you, jot down some names today and send them to the executive office right away.

Book Reviews

Drying Rates of Thin Sections of Wood at High Temperatures.* By Herbert O. Fleischer. The physical phenomena involved in the drying of veneer as compared with the drying of lumber have never been thoroughly studied. This fundamental study of drying rates of thin sections of wood at high temperatures casts much light on the drying mechanism involved in the usual veneer drying processes.

Wood sections in thicknesses of 1/32-inch to 1/4-inch were dried at temperatures up to 350° F. under closely controlled conditions of humidity and air circulation. In pieces 1/4-inch thick, and in some cases 1/8-inch thick, drying rates were found to be comparable to those for lumber, that are generally assumed to be controlled primarily by the rate of diffusion of water through the wood. In thinner sections the drying did not appear to be retarded by the slow diffusion process, but proceeded as rapidly as heat could be supplied to evaporate water from the wood.

Based on considerations of heat transfer, a method of expressing drying rates in simple mathematical terms was developed. The significance of the various factors affecting drying rates was established. Some observations are included on the drying defects that may occur when thin wood is dried at high temperatures.

It is expected that the mathematical methods outlined in this study may be applied to practical problems of veneer drying rates, such as the development of drying rate control charts for commercial veneer drying operations.

"On the Properties and Testing of Wooden Doors," by Osmo Liiri, Publication No. 109, The State Institute for Technical Research, Helsinki, Finland, 1953, 23 pages, 8 Fig., In Finnish with English summary. Reviewed by L. W. Crandall, Fulbright Research Engineer. Laboratory tests on nine types of flush doors and three types of panel doors are described and compared. Flush door core types include pine edgings both parallel and perpendicular, plywood strips, insulating fiber-board, and corrugated paper. Faces were of birch plywood, 3-ply and 4-ply as well as 1/8" hardboard. Panel doors were all of Finnish pine.

Strength properties were tested by racking parallel and by compression perpendicular to the plane of the door. Curves are presented showing load vs deflection for the various door types.

Cyclic moisture exposure tests were also made using both- side and one-sided exposure. Comparative measurements are given for warping, twisting, and swelling of doors. Moisture content of the doors varied from 10 to 30%, temperature from 68° to 104° F. and relative humidity up to 95%. Both series of tests indicated that the swelling of doors was 0.1 to 0.2% in length and in width.

Phenol-formaldehyde and resorcinol-formaldehyde glues were found to be most resistant to cycles of wetting and drying. The more symmetrical and homogeneous core types twisted the least. Results of this series of tests would seem to justify the current increase in favor of the flush type door.

* Fleischer, Herbert O.: Drying rates of thin sections of wood at high temperatures. Bulletin No. 59, Yale School of Forestry, New Haven, Conn. 86 pp., 3 plates, 19 figs. Price $1.50.

Water Tupelo Kiln Schedules

The following are commercial kiln schedules for water tupelo inadvertently omitted from the comments of Geo. C. Lucas (May Bros.) on the paper "Kiln Drying of Water and Swamp Tupelo" by J. M. McMillan, Dec. 1953 issue of FPRS Journal (V. 3, No. 5) p. 189–196.

Time Days	Temperature: Dry bulb °F.	Temperature: Wet bulb °F.	Relative humidity Percent	Moisture content: Sample Percent	Moisture content: Wafers: Core Percent	Moisture content: Wafers: Shell Percent	Moisture content: Wafers: All Percent
			¾-inch				
Start	120	119	97	135	141	109	121
1	125	124	97	---	---	---	---
2	130	129	97	---	---	---	---
3	130	129	97	65	---	---	---
4	140	135	87	55	60	42	40
5	145	140	87	35	57	30	37
6	150	140	76	---	---	---	---
7	150	140	76	32	40	15	30
8	160	140	58	---	---	---	---
9	160	140	58	13	20	10	14
10	160	135	50	6	14	9	10
11	165	135	44	5	9	6	8
*11¾	165	135	44	4	6	5	6
			5/4-inch				
Start	125	124	97	147	150	140	145
1	130	129	97	---	---	---	---
2	135	130	86	---	---	---	---
3	140	135	86	---	---	---	---
4	150	140	76	31	75	25	66
5	150	140	76	---	---	---	---
6	150	140	76	13	20	14	16
7	160	140	58	6	10	5	8
*7¾	166	135	52	5	7	4	6

*After drying, the charges were steamed 2–4 hours to relieve set.

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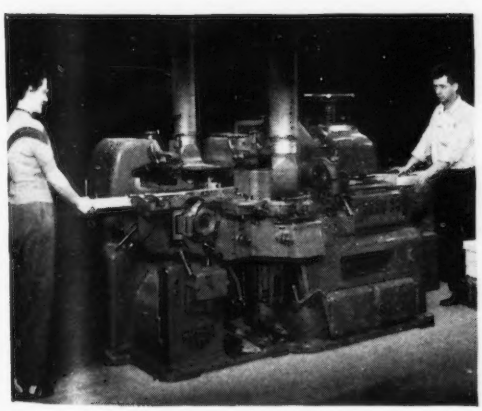

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Our operators find this Mattison No. 276 very easy to set up, due to the accessibility of all the adjustments and controls. Vertical and cross adjustments of the cutterheads are made positively and quickly, and the hand locking wrenches which are attached to the machine simplify setting of the guides. Another feature is that it "stays put", which is no doubt due to the rigid construction, precision manufacture, and advanced engineering design. The outboard bearings eliminate vibration in heavy cuts, and we believe that any high speed moulder spindle should have an outboard bearing.

We are confident that this machine will continue to perform efficiently for a great many years.

Yours very truly,

IMPERIAL FURNITURE COMPANY

A. F. Christy

A. F. Christy
Plant Manager

- Imperial Furniture Company's reputation for building a high quality line of tables is in a good measure due to precise fabrication methods which insures consistently accurate results and proper fitting of all parts. Mr. A. F. Christy, Plant Manager of Imperial, has been around the woodworking industry for a good many years and knows what he wants and has to have in the way of production and accurate results. The above letter telling of his experience with the Mattison 276 Moulder is an example of what this machine is doing for a good many others. For complete information on the Mattison 276 High Speed Electric Moulder, ask us to send you our latest free circular.

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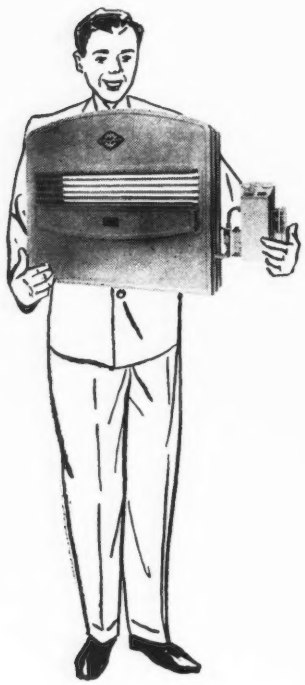

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